

ORGANIZING FOR SCIENCE

The Making of an
Industrial Research Laboratory

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For Appa and Amma

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I must also state that Chapter 3 was written during my tenure as ICSSR Fellow at Delhi School of Economics and Chapter 6 was published earlier in *Contributions to Indian Sociology*.

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CHAPTER I

THE PROBLEM

I

This study is an attempt to understand the problems of scientists in an industrial research laboratory in Delhi. It is written with the basic belief that the world of scientists in an industrial research laboratory can be treated as a microcosm of the problems of science and technology in a developing society. It holds that to understand the problems of science and technology, one has to understand not only the history of the industry and the technology, but also the changing relations between science and technology, not merely in one country but in a comparative framework. The problems of scientists vis-à-vis industry have also to be located in a wider framework, that is, the sociology of a science laboratory has to be an intrinsic part of the sociology of a developing society. The wider questions of the bigger problem have to be reflected in the more limited study; a sociology of science in India has to be a study of underdevelopment. It is only within such a framework that the problems of the transfer of technology assume a meaning and take on a connotation beyond the provincial explanations of management theory—a boundedness that facilely believes that the only solutions to success lie in the alterations of a few organizational variables—motivation, career structure, goals and hierarchy.

The necessity of adopting a wider socio-historical perspective was emphasized by the scientists themselves. A former Director General of the Council of Scientific and Industrial Research of India captured it eloquently in a set of interviews:

Sheshadri died last week. There was hardly a murmur, only an obituary short and antiseptic, ejected out of a machine, a facile act rubbing out a debt to the past. Who remembers Bhatnagar or Saha today? Yes. I admit your science of science as it styles itself is a big subject. I met Derick de Solla Price once, when I was Director General. He came to me full of his

theory of the exponential growth of science, graphs, calculators and all. Statistics, elegant and lifeless. Statistics do not bleed. Body counts of periodicals, scientists, publications, these are indices that do not add up to science. They reveal little about the content of science. Say little about questions I am interested in. Why is it with all the money we are pouring into science today—350–400 crores recurring, why is it that science in India has failed, when in the years of colonialism it was such a vital force? This is what we must try to understand. You can't do that if you begin with the ready-made organizational scripts the CSIR provided in 1947. You have to shift your time markers back to the very beginning. The genesis is all important even if the first acts ended in abortions.

Yes. It is a question of perspective and perspective is all important. I think it is a function of two elements, a conceptual framework and a sense of history. To this possibly I would add a third—the choice of problems, the search for the big questions, not always answerable. Science can ask limited questions, but sociology cannot limit its questions, especially those it asks of science. I think it is specially important today when social scientists come armed with questionnaires ready to wrestle with reality in two hours, regimenting responses, the yeses and nos, as if an aggregation of these is an approximation of reality. Henry Tizard once said a scientist is judged by the choice of problems, and I will begin by stating mine. Why is it that science in India has remained aloof and elitist? What is the actual relation between science and technology? What is the relation of the state to the innovation process? I would like you to provide an analysis of a technology; to consider this cluster of variables—state, science, technology. A study of the inter-relationships of these three have all the makings of a fascinating sociological exercise. Let us begin with history.

History is important. But I think we read the wrong history books. We read the history of physics, Rutherford and Dirac at Oxford and Cambridge, of a science that believed in the ideology of science for science's sake, that held it could sustain itself on shoestring and beeswax. This selective study of science created a myth, a myth of the science for science's sake, a myth we will have to dispel. We will have to begin not with physics, but with chemistry and the history of chemistry in Germany in the 1870's.

* * *

I admit this reflects a frog-in-the-pond syndrome. To the frog the pond constitutes the limits of the universe. My pond was the laboratory. But rather than transcend this bias, I shall articulate it, seeking to find and capture the problems of a wider society within the confines of one institutional structure—an Industrial Research Laboratory. The industrial research laboratory reflects at best the dialectic between nationalism and imperialism and it is in the interplay of the two forces that science and

scientificized technology play a crucial role. The phenomenon of industrial research is something unique. It reflects an institutional complex that arose late in history, the rationalized application of science to the problems of manufacture. One should analyse it with special reference to the development of synthetic chemistry in Germany.

In the following section we shall analyse the nature of this development.

II

Industrial research as an organizational innovation was a German contribution and it was the outcome of a particular type of relationship between the university, industry and the state.

Scientific education in Germany was the responsibility of the state. As a result of state subsidies higher education was cheap and a university course in chemistry cost a mere £ 12 a year. (Haber, 1958, p. 71.) The rewards for science were high and German scientists like Liebig, Kekule and Helmholtz were not only highly feted but handsomely paid. (Haber, 1958, p. 71.) The state of professionalization was such that a student could visualize a career in science either in the universities, or in the research laboratories sponsored by German firms alive to the commercial possibilities of science. Joseph Beer in his *Emergence of the German Dye Industry* describes it thus: 'Co-operation with the universities was so actively sought that a veritable competitive struggle arose between them over the control of the most important laboratories. In time, each managed to establish strong ties with certain schools to the exclusion of others'. (Beer, 1959, p. 64.)

The symbiosis between the university and industry went even further. Paul Hohenberg points out that entrepreneurs were active in entrusting managerial powers to scientists, thus shifting the focus of decision-making from the factory to the laboratory. What was even more impressive was the alacrity of the entrepreneur in backing every promising scientific move with the required capital. The outstanding instance was the case of the Badische Anilin und soda-fabrik (BASF) which invested eighteen million marks in the development of synthetic indigo and did not sell a pound of it until eighteen years after the research was begun.

The nature of risk-taking that confronted science-based firms also brought about certain radical changes in the nature of these

firms. The production of synthetic indigo illustrates the nature of this transformation. Indigo was synthesized from a derivative of cinnamic acid by Adolf Von Bayer in 1880 and, as already noted, it took eighteen years from the laboratory process of Von Bayer to commercial production in 1897. It was the uncertainties inherent in the process which prompted certain changes in the nature of the science-based firm. It brought about the depersonalization of the Schumpeterian innovator. (Hohenberg, 1967, p. 61.) The first phase of the synthetic industry was marked by inventors like Perkin, who not only synthesized Mauvine, but, realizing its commercial possibilities, also set up a successful firm. The acts of invention and innovation were combined in the same person. In the second phase of chemistry, the inventor might have been a single individual but innovation demanded huge investments and a large organization which no single individual could afford. Innovation became corporate. The synthesis of indigo in fact heralded the rise of a new kind of firm—the science-based multinational. This was a knowledge-centered firm which applied science to the creation of new commodities. Secondly, not only was production on a large scale but the uncertainties inherent in the process necessitated the integration of all the operations concerned. The firm had to encompass every aspect of the innovation chain from raw materials, intermediaries, by-products, research, production, markets, advertising and after sales service. The development of synthetic indigo was enacted within a competitive framework which strained the finances of both Hoechst and BASF. BASF, which was first in synthesizing indigo, soon found itself in danger of being outstripped by Hoechst. The firms realized that such competition was an uncertainty they could well do without, and this led to the idea of a fusion of interests between the various synthetic dyestuff groups, a federated structure, an *intergemeinschaft*. Elaborate negotiations resulted in the amalgamation of three firms into the first of the great scientific cartels—IG Farben. The formation of IG Farben anticipated by a few years the other chemical multinationals, ICI in Britain and Dupont in USA (Beer, 1959, p. 125.)

The outstanding characteristic of the structure of German science lay in the effective integration it had achieved between science and technology. The development of professionalized science in Germany, integrated to industry and encouraged by the

state, stands in sharp contrast to British moves to reform science. In 1895 the Germans had established the *Physikalisch Technische Reichanstalt*. British scientists agitated for an equivalent—The National Physical Laboratory, which was established as a laboratory for the maintenance of national standards and the testing of instruments in 1902. The latter was the first instance of state participation in research. A few more feeble moves resulted in the establishment of the Imperial College of Science and Technology and provision in the National Insurance Act for a medical research fund.

The inception of World War I found Britain fighting an enemy on whom she was totally dependent for 'optical glass for her range finders, the dyes for her uniforms, magnetos for transport, tungsten for steel, zinc for smelting'. (Armytage, 1965, p. 215.) One of the outstanding instances of such inadequacy was the dyestuff industry, 88 per cent of which was controlled by the Germans. The first steps the British government took were feeble ones—an attempt to float a National Textile Corporation. Meanwhile, scientists keen to achieve an institutional integration of science and technology formed an unofficial pressure group, 'the Neglect of Science Committee'. It is interesting that almost all the participants at the conferences convened by the committee conceded the excellence of British achievements in pure science. What they criticized was the insufficient application of science to industry. They felt that the true applied science laboratory had not yet emerged in England. (Levine, 1967, p. 71.)

It was precisely this disjunction that the scientists set out to bridge. They persuaded the Board of Trade and Education to recognize the need for governmental assistance for research in industry, which led to the establishment of the Haldane Committee. Realizing that even this was inadequate the government established the Department of Scientific and Industrial Research in 1916. The NPL was removed from the control of the Royal Society and placed under the aegis of the state. The government also provided for the application of science to specific industries. By 1920 over twenty industrial research associations dealing with photography, glass, fuels, radio, etc. had been established.

Having briefly analysed the development of industrial research in Germany and Britain, let us now proceed to understand the

institutional implications of industrial research for the former colonized societies like India.

III

The history of industrial research can be divided into several phases, the first of which centres around the synthesis of the aniline dye. In this phase processes were still simple, knowledge of the technique bordered on the empirical. The manufacturing units were small and none of the products managed to supplant natural vegetable matter. The second phase, which began with the synthesis of alizarin, was far more scientific, with scientists systematically experimenting on molecular dyestuffs architecture according to the theoretical blueprints furnished by Kekule. As a result of the researches almost all the natural dyestuffs except indigo were displaced. The production of the madder dye, estimated at 70,000 tons annually, declined and large areas in France which specialized in its production faced ruin. It was the profits from the synthesis of alizarin that enabled Hoechst and BASF to finance the long and uncertain investigations into the synthesis of indigo. Synthetic indigo introduced into the market in 1897 forced natural indigo, on which India had a monopoly, into obsolescence. Within a span of ten years exports of indigo fell from 19,000 tons in 1895-6 to approximately 11,000 tons in 1913-14. Over 200,000 acres of land devoted to indigo lay idle. With the start of the War there was a temporary boom when the British army needed dyes for khaki uniforms and 21,900 acres were sown to meet the demand. One must emphasize that it was not the foreign planters who were to bear the costs of obsolescence but the tenants. It was this that led to Gandhi's movement at Champaran. Mahatma Gandhi, whose nationalism had so far confronted the obsolescence of man by machine, came face to face with the obsolescence created by science.

The next phase in the rise of chemistry culminated in the synthesis of ammonia. Prior to World War I Britain and Germany depended on the Caliche deposits of Chile for their fertilizer inputs. Chile supplied 55 per cent of the world's requirements. The Malthusian spectre of population outrunning food supply attracted the attention of scientists to the problem. In 1898 Crookes hinted that the solution lay in the working out of a commercially feasible

process for tapping nitrogen from the atmosphere. The problem demanded a remarkable synthesis of scientific insight and technological competence and inevitably the solution came from Germany, from the BASF scientists, Haber and Bosch. It is interesting that the time gap between a scientific idea and its commercialization was already decreasing. In the case of indigo it took eighteen years, but with synthetic ammonia it was a mere six years. The Haber Bosch process, regarded as one of the outstanding feats of scientific engineering, could not have been attained without state assistance which was manifested in liberal subsidies. This alliance of the university scientist, the entrepreneur and the state created an institutionalized system of obsolescence—industrial research—which wrecked the Chilean economy, where the export of fertilizers accounted for 80 per cent of the government's income.

This book takes as its basic problem a sociological understanding of how societies like India responded to the phenomenon of industrial research.

CHAPTER 2

THE RISE OF INDUSTRIAL
RESEARCH I

I

The introduction of western science in India can be divided into three phases. The first of these was called the era of the Great Surveys. It was a period that involved the development of a host of field organizations under the inspired impetus of the Asiatic Society of Bengal. The establishment of the universities in the presidency towns of Calcutta, Bombay and Madras and their transformation from mere examining bodies to active agencies combining the functions of teaching and research constitute the hallmarks of the second phase. The relation of science to the economy was not the primary concern in either of these two phases. It is only in the third phase that systematic institutional links were sought between science and the Indian economy. This culminated in the establishment of agricultural research and in the eventual rise of the industrial research laboratory.

Although this book is basically concerned with industrial research in India, a sociology of industrial research necessitates a historical perspective and demands that we reconstruct the first two phases of Indian science. There are two reasons for this. First, there is an element of continuity between the three phases. But more importantly, the debates relating to the establishment of these organizations did not deal only with managerial issues. They were concerned not merely with the structure of science but with the evolution of Indian society.

The institutionalization of western science in India commences for all practical purposes with the establishment of the Asiatic Society of Bengal in 1784. The Society was established by Sir William Jones, a distinguished orientalist and judge at the Supreme Court of Calcutta. Like a few other officers of the East India Company, he found in India not just an expanse of territory

to be conquered but a new and almost untapped realm of knowledge for the West. William Jones was not the first of these investigators. He had been preceded by a number of scholars in the eighteenth century. In geography, D'Arville was already collating the work of Jesuit missionaries like Claude Boudier, Barbier, Bouchet and Calmettee. In botany, the amateur researches of Heinrich Van Rheed had resulted in the twelve-volume *Hortus Malabaricus*. The Tranquebar missionaries had established the United Brotherhood which was dedicated to the pursuit of botanical researches in India. The publications of these scholars were scattered randomly in British and French journals of the time. (Bagchi, 1965, p. 11.) Jones realized that the isolated efforts of these scholars were not enough. He understood the collective nature of the scientific act and the importance of communication and exchange in science. He sought to provide for a co-ordinated body of knowledge through the establishment of the Asiatic Society. Jones, as Suniti Kumar Chatterjee pointed out, was not the first orientalist, but he was the first man to institutionalize orientalism as a specific branch of intellectual endeavour. (Chatterjee, 1946.)

On 15 January 1784, William Jones, along with thirty other officers of the East India Company, inaugurated the Asiatic Society in the rooms of the Supreme Court of Calcutta. In his inaugural address he stated the objectives of the society.

You will investigate whatever is rare in the stupendous fabric of nature, will correct the geography of Asia by new observations and discoveries, will trace the annals and even the traditions of those nations who from time to time, have peopled or desolated it, will bring to light the forms of government with their institutions civil and religious; you will examine their improvements and methods in arithmetic and geometry, in trigonometry, mensuration, mechanics, optics, astronomy and general physics, their systems of morality, grammar, rhetoric and dialectic, their skill in chirurgery and medicine, and their advancement whatever it may be in anatomy and chemistry. To this you will add researches into their agriculture, manufacture and trade, and whilst you enquire into their music, architecture, painting and poetry, will not neglect those inferior arts by which the comforts and even the elegances of social life are supplied or improved. . . . If it is asked, what are the intended objects of this enquiry, within these spacious limits we answer, man and nature, whatever is performed by one or produced by the other. (Chatterjee, 1946, p. 413.)

The British officers who established the Asiatic Society transplanted with them an early characteristic of western science of the time, the cult of the amateur. The objectives of the Society had all the imperialism of the amateur. The only boundaries it accepted were the geographical limits of Asia. The Society was closely modelled on the hebdomadal gatherings of the Royal Society of London, a body which for the most part came from the leisured classes that pursued science for education and entertainment. Jones hoped that this group of amateurs would advance to maturity just as the Royal Society, which was initially only a meeting of a few literary friends at Oxford, rose gradually to a splendid zenith when Halley was its Secretary and Newton the President. In the India of the time the dominance of the amateur was inevitable. Lewis Fermor points out that 'during the early days, the East India Company employed no scientists as such although the Company entertained the services of medical officers, surveyors and assayers at the Mint. As a consequence, the early scientific work in India was practically all amateur work done in their spare time by medical men who were interested in science, by enthusiastic army officers, and by officers in civil employ' (Fermor, 1935, p. 18.) The Asiatic Society provided full freedom to these amateur scientists by providing them not only a forum for discussion, an avenue for publication in *Asiatic Researches* and the journal of the Society but with that absolute requisite of the field sciences, the museum. It is the field activities of the Society that led to the establishment of the Great Surveys.

The early issues of the Society's journal were dominated by orientalist. The only scientific contributions came from mathematicians like Barrow and Pratt. It was only in 1808 that the dominance of the orientalist began to recede, when the Society was bifurcated into two sections grouped under the rubric of literature (philosophy, history, antiquities) and the other grouped under the general label of physics which included natural history, philosophy and medicine. The second committee lay dormant for twenty years and its revival signalled the outburst of activities in the biological and geological sciences, out of which came the Great Surveys.

As one of its first Indian directors pointed out, the Zoological Survey, was a product of the evolution of over a century of research in systematic zoology initiated by the naturalist members

of the Asiatic Society. The Survey was an eventual organizational spin-off formed by converting the zoology and anthropology sections of the museum into a separate government department. The superintendent of the relevant sections became the first director of the Survey in July 1916.

The Asiatic Society was not involved in the establishment of the Royal Botanical Gardens, the first institution for botanical research in India, but it did play a crucial role in its development. The Sibpur Gardens were established to facilitate the introduction and acclimatization of economic plants into India. James Falconer, a member of the Society, recommended the introduction of *Cinchona* plantation into India. Falconer also established the feasibility of tea cultivation in India, and, under the aegis of William Bentick, the officers of the Sibpur Gardens established the industry in 1835.

But the epitome of the Imperial Survey was the Geological Survey of India (GSI). The first contributions to Indian geology were the inspired work of amateurs whose researches were published in the journals of the Society. Voysey, the father of Indian geology, was attached to Colonel Lambton's survey as a surgeon. P. M. Benza, who contributed to the geology of the Nilgris, and Malcolmson to an understanding of the Deccan Trap, belonged to the Madras Medical Service. Adams, Hardy, Spilsbury, all contributors to early Indian geology, belonged to the Bengal Medical Service. The official history of the GSI begins with the rise of the coal mining industry in India when a coal committee was established by Auckland in 1795 and recommended the geological survey of the coal belt of India. The East India Company obtained the services of David Hiram Williams of the Geological Survey of Great Britain. Williams, who surveyed the Ramgarh and Karimpura coalfields, laid the foundations of the GSI in 1854. In its early years, the GSI was housed in the Asiatic Society.

The GSI offered great possibilities for industrializing India and even though the efforts of the Survey represent imperialism at its best its researches had compiled a vast record of the mineral wealth of India. Yet little or nothing was done to utilize it. As early as 1902 the Survey possessed a nucleus of experts on industrial minerals ready to spearhead an industrial utilization drive. The Government vetoed all such moves, contending that the Survey was

established to facilitate the export of minerals to other countries and infact transferred these experts from the Survey to the new Bureau of Mines, an organization with the purely administrative function of inspection to assure the implementation of safety rules in the mines. 'The mineral development of India was left largely in the hands of private enterprise which concentrated mainly on rich occurrences of ore and minerals whose exploitation for export or other use required little risk and practically no capital.' (Fox, 1943, p. 14.)

Throughout the eighteenth and nineteenth centuries, a host of organizations broke off from the Asiatic Society to lead an independent existence of their own. The final roster of institutions the society initiated, suggested, nursed or nurtured, included the Royal Botanical Gardens, the Indian Museum, the Zoological Gardens, the Survey of India, His Majesty's Mint, the Meteorological Department of the Government of India, the Linguistic Survey, the Medical College of Bengal, the School of Tropical Medicine, the Geological Survey and the Anthropological Survey of India. With the formation of each of these organizations there was a corresponding decentralization of activity. Scientific activity now tended to be concentrated in the Surveys and the scientific researches once published in the general compendiums of the Society were now localized in the specialized memoirs of each Survey. The specialization of science was eventually to have an indelible impact on the Society (Brahmachari, 1931, p. xxiii) and by 1896 Alfred Pedler, Professor of Chemistry at Presidency College, could not decide whether the Society was an anamoly or an anachronism. The genesis of the Society and its social distance from the scientific centres of Europe had rendered it a unique, a group of amateurs in the age of the specialist professional, but Pedler pointed out that the development of scientific societies in Europe was towards ever-increasing specialization. 'Each specialization had its own society in Europe'. There was already a tendency for British officers to submit their researches to these magazines, for they were then sure that their papers would find a receptive audience. They preferred this to sending contributions to the *Journal of the Asiatic Society* where a paper could be the only one of its kind. In prescient words, Pedler remarked 'In the case of Europeans who are temporarily resident in this country hoping to return to their native land later on this tendency can readily be

understood and perhaps excused. On the other hand, for workers whose home is in India, and who will probably do all their work here, there is not the same reason for sending original papers to societies in Europe but the natural tendency should be to contribute to societies like our own, for their work would be published in the land in which they live and where they would be fully recognized by their countrymen. Indeed it might be argued that it borders on want of patriotism for the native to send his original work to be published in Europe'. (Pedler, 1896, p. 18.) But soon after Prafulla Chandra Ray's paper on mercurous nitrite appeared in the *Journal of the Asiatic Society*, its review in *Nature* delivered a coup de grace to the pretensions of the Society. 'The *Journal of the Asiatic Society* of Bengal can scarcely be said to have a place in our chemical libraries. The current number, however, contains a paper by Dr. P. C. Ray of Presidency College, Calcutta, on mercurous nitrite that is worthy of note'. (Ray, 1932, p. 114.)

The Society's preoccupation with its amateur membership is reflected in a series of Presidential addresses (Pedler 1896, Brahmachari 1931, Fermor 1935, Fox 1943). The majority of them saw in it not the vestige of an old era in science but property to be preserved, by adapting to new situations. The members emphasized that, while it led to greater efficiency the specialization of science brought with it a certain narrowness. There was a necessity to transcend the specialization and excessive technicality of modern science, for communication between the scientific estate and the political world and to translate the esoteric dialects of science into a popular idiom. These requirements led to the Indian Science Congress in 1915, the first meeting of which under the presidency of Asutosh Mukherjee was held in the rooms of the Asiatic Society. The proceedings of the Congress were published by the Society and the day-to-day administration between sessions delegated to it. The necessity of an academy or institute encompassing the various specialist societies and representing the scientific profession vis-à-vis the state was recognized by the Society. At the Indian Science Congress of 1934, the Society helped inaugurate the National Institute of Sciences, a body equivalent to the American Academy of Sciences. The Institute was housed for 10 years in the Royal Asiatic Society. Lewis Fermor, its president also served concurrently as the first President of the National

Institute of Sciences. Through the generosity of the Society two more functions were usurped by the various bodies it had created and once again the Society found itself dessicated, irrelevant and dying. The best epitaph for this finest gift of British imperialism was written by one of the most nationalist of scientists. In his Presidential Address to the Society, Meghnad Saha remarked, 'It appears to me that the career of the Royal Asiatic Society of Bengal has been somewhat like its great contemporary, the Great Banyan tree of the Sibpur Botanical Gardens. Like that king of trees, it has thrown all around itself aerial roots which have developed into independent self-contained institutions having little contact with the mother body. The original society is now reduced to a mere trunk and unless we can infuse it with new life giving activity, it may become like the trunk of the old banyan tree'. (Saha, 1946, p. xvi.)

By the thirties and forties of the twentieth century, the Society was an anachronism, a coterie of British gentlemen in the age of nationalist science, generalists in the age of the specialist, a group of amateurs in the age of the professional. The centre of gravity of science had shifted to the universities by the beginning of the century and it is the rise of science in the universities that we shall now proceed to explore.

II

The inspired initiative of the Asiatic Society in the establishment of the network of institutions India has inherited, provides a contrast to the Society's role in the introduction of western science into the educational process. David Kopf (Kopf, 1969, p. 24-5) has emphasized the tolerance and cosmopolitanism of this group which accepted the diversity of cultures. The Society attempted to preserve and perpetuate native educational and legal institutions, but such a preservationist attitude could not last long.

The industrial revolution had transformed the relations between India and England, rendering the former a market for British goods. It ushered in a new kind of consciousness. The aggressive middle class that it brought into being saw in India a laboratory, a testing ground for British ideas in the realms of law, economics and education. When the Charter Act of 1813 provided a grant of Rs 100,000 for the revival and improvement of science and

literature in India, the orientalist in the Company used it to establish Sanskrit colleges many Indians, including Ram Mohan Roy, objected. Roy felt that the establishment of such a college destroyed 'the sanguine hopes of the native intelligentsia for courses in mathematics, philosophy, chemistry and anatomy'. The establishment of Sanskrit schools specializing in metaphysical niceties was regression to a pre-Baconian universe. In his letter to Amherst, Roy recommended the establishment of a college staffed with talented scientists from Europe to teach mathematics, natural philosophy, chemistry and anatomy. The orientalist like Prinsep and Colebrooke, however, felt that tuition in the western sciences was inadvisable. Prinsep, along with other members of the Asiatic Society like Reuben Barrow, William Jones, Henry Colebrooke, was startled that the ancient Hindu sciences had rudimentary conceptions of the binomial theorem, Euclidean geometry, descriptive linguistics. It was this knowledge that, after numerous transplants, produced the philosophy of Bacon, Newton and Locke and Prinsep saw no reason why their ideas in turn could not be grafted back to the Sanskrit system which could then retain its own individuality. (Prinsep in Sharpe, 1919, p. 126.)

The orientalist attitude soon fell out of fashion under the utilitarian ideas of Mill. The appointment of Macaulay, the British recognition of the unanticipated popularity of the English language among the intelligentsia, spelled the decline of the orientalist view. Macaulay's famous minute swung the pendulum the other way. Macaulay had no knowledge of Sanskrit or Arabic but was told 'That a single shelf of a good library was worth the whole literature of India and Arabia and when we pass from the works of the imagination to the works in which facts are recorded and general principles investigated, the superiority of Europeans becomes unmeasurable' (Sharpe 1919, p. 107.) Macaulay had cold contempt for the ideas of Prinsep and the orientalist and remarked 'we are a board for wasting public money, for giving artificial encouragement to absurd history, absurd metaphysics, absurd physics, absurd theology, for raising a creed of scholars whose education is totally useless to them that when they have received it they must either starve or live on the public all the rest of their lives' (ibid, p. 117.)

To Prinsep's conception of an alternative science he retorted 'the choice is between European science and medical doctrines

which disgrace an English farrier, astronomy which would be the laughter of girls at an English boarding house, history abounding in Kings, thirty feet high, and reigns a thousand years long, geography made of seas of treacle and butter.' (ibid, p. 111.) He also vetoed all further support to the madrasah and Sanskrit colleges and the printing of Arabic and Sanskrit books. The annual meeting of the Asiatic Society in 1835 condemned him for it.

Sumit Sarkar points out that 'little remained of the Baconian dream of Roy, of his stress on mathematics, natural philosophy, chemistry, anatomy and other useful sciences in the Macaulay-style literary education introduced in 1835.' (Sarkar, 1973, p. 150.) Macaulay's minute and Sir Charles Wood's despatch of 1854, led to the establishment of the universities in the Presidency towns of Bombay, Calcutta and Madras. These universities were modelled on the London University of the time and their role was restricted to the task of mere examining institutions with no control over recruitment or curricula, without the function of teaching or research. The courses possessed a distinctly literary bias, and it was not till 1890 that Calcutta instituted a B.Sc. degree. The general state of education produced a series of reactions. The first reaction against the literary bias of the colleges was a demand for greater emphasis on scientific research. The second tended to emphasize technical education to provide sufficient training for Bengali entrepreneurs. If the first two moves tried to improve and diversify the education offered in English, the third group, concerned with the alienation of the intelligentsia from the masses, advocated vernacular education. All three groups attempted to create a series of parallel structures to those of the British regime. And it was only with the partition of Bengal that these collective moves experienced a catalysis incorporated into a political movement. One of the most remarkable of these early attempts was Mahender Lal Sircar's effort to establish the Indian Association for the Cultivation of Science.

Mahender Lal Sircar (1833-1904) was a product of the best education the anglicized schools of the time could offer. An outstanding student of Hare School, he had a brilliant career both at Hindu College and at Calcutta Medical College and graduated in 1863. The struggle to synthesize a new Indian culture is evident in the biography of the man. One of the earliest members of the Medical Association, who initially scoffed at non-allopathic systems

of medicine, Sircar became the foremost advocate of homoeopathy, an act for which many of his allopathic counterparts wished to strike him off the roster of the Medical Association. Sircar realized that with the marginal exception of the medical colleges of the time there were no facilities for teaching or research in the educational institutions of Calcutta. He knew that the mere introduction of a few books on science in the curriculum would not create a culture of science. It required original research, and public appreciation and support for science as an autonomous intellectual pursuit. Finally, he knew that science in India had to be under Indian control. Organizations like the Great Surveys equipped with facilities for research did exist at the time but they were closed to Indians and the Asiatic Society of Bengal remained under the control of the British. He tried to create an institution that would train scientists to undertake original research and to create an appreciation of science among the masses. In 1869 Sircar outlined plans for the Indian Association for the Cultivation of Science in the *Calcutta Journal of Medicine*. Sircar's cultural nationalism is obvious in documents containing his references to the development of the positive sciences among ancient Hindus and his emphasis on the absolute need for the physical sciences in the regeneration of the Indian peoples. (Sen, 1976, p. 1.) India, he believed, was perishing from lack of knowledge and the Association was established to restore the old Aryan vigour of intellect. But Sircar's vision of science also went further than this. He sought to rescue science from western civilization. In a speech before the association, he declared,

I see with the eye of faith that regenerated India has a mission to fulfill in the future. On the stable basis of the physical sciences, she will have to build a philosophy and a religion which will be the regeneration of the world. The civilization of the west notwithstanding its profession of the blessed religion of love, preached by Jesus Christ two thousand years ago, is still threatening to become more and more the civilization of iron and blood, whose aim seems to be to polish the weaker nations and the so called savage races off the face of the earth, forgetful or unmindful of the cardinal doctrine of that religion; that of one blood hath God made all nations of men. This aggressive civilization against which the Christianity of Christendom seems absolutely impotent will have to be humanized and whence will this humanizing influence proceed? Even at the risk of raising a smile or even the laughter of contempt at this audacious declaration, I

cannot help giving expression to my belief that that influence will proceed from India. (Sircar, *IACS Annual Report* 1900, pp. 25-6.)

Sircar's vision of the Indian Association for the Cultivation of Science deserves to be contrasted with William Jones' conception of the Asiatic Society of Bengal. Jones' Asiatic Society was a product of British administrators wishing to indulge in scientific activity halfway between 'languid reminiscences and overzealous activity.' A creation of British colonialism, it remained for all practical purposes under British control. In his first discourse, Jones did not even recommend the membership of Indians and the first Indian, Dwarkanath Tagore, was only admitted in 1832. As late as 1875 no Indian played a decisive role in the council although Rajendra Lal Mitra and Asutosh Mukherjee were to become strong contenders towards the end of the century. Whereas the Asiatic Society sought to focus western interest on the Indian sciences and the arts, Mahender Lal Sircar's association was to be Indian and under strict national control. Its focus was not to be restricted to India alone. He claimed that 'India of her own accord, unaided and unsolicited, will equip and send out scientific expeditions. No part of the world requiring exploration will be without explorers from India. Not a single phenomenon can occur either in the heavens above or the earth below, which can be predicted beforehand and the observation of which might be of scientific interest and importance, to which India will not send her scientific men to observe and record.' (Quoted in Brahmachari, 1942, p. 4.)

The Asiatic Society retained its amateur status long after the Royal Society on which it had been modelled passed out of the control of the generalist amateurs. Mahender Lal Sircar was acutely aware of Charles Babbage's attack on the dilettantist state of the Royal Society and also of his advocacy of state patronage of science. Babbage emphasized that the pursuit of science must constitute a distinct profession, as in Germany. He, Brewster and others argued for the formation of an association to protect the interests of British science, which eventually culminated in the establishment of the British Association for the Advancement of Science. The individuals who founded this organization, interestingly enough, called themselves The Cultivators of Science.

Sircar's proposal for the cultivation of science in India were influenced by Babbage. (Sen, 1976, p. 4.) Sircar believed that science in India could not grow through the efforts of the leisured classes and had no faith in unpaid workers. 'We must not forget that men have stomachs as well as minds. The mind must have leisure to think that it may think with any advantage and this can only be secured by providing for the demands of the stomach. In Europe and America this leisured thinking is secured largely by the state and other appointments. In our country such appointments do not exist and it is chiefly with a view to supply the deficiency that I have striven to found this Association.' (Sircar, *IACS* 1895, p. 13.) Along with the urgent need to professionalize science, Sircar advocated the necessity of specialization. In his proposal he remarked, 'the extent of the field covered by each branch of science is so vast that it is not possible for a single mind to master the details of all, far less to extend its boundaries. A single branch is more than sufficient to form one man's speciality. This necessitates the serious cultivation of science, a division of labour, a differentiation of function and duty. It is necessary therefore to have sections in the association devoted to branches which ought to be separately studied for their due cultivation.' (Quoted in Brahmachari, 1942, p. 2.) Sircar visualized seven such sections: general physics, chemistry, astronomy, systematic botany, systematic zoology, physiology and geology.

The provisional committee for the Association met on 16 December 1875 under the chairmanship of Eugene Lafont, a Belgian missionary teaching at St. Xavier's College, Calcutta. Lafont was that rare missionary who believed that of all the gifts the West was bringing to India the study of science was the only safe one. (Lafont, *IACS*, 1904, p. 29.) He virtually collaborated with Sircar in establishing and sustaining the organization through its early years.

Sircar stated the objectives of the Association before the committee. He said 'it was to enable the natives of India to cultivate science in all its departments with a view to the advancement of original research and (as it will necessarily follow) with a view to its varied application to the arts and comforts of life' (Sen, 1976, p. 9.)

The Indian Association was formally established on 29 July 1876. It started a course of lectures with Lafont, Sircar and

Taraprasanna Roy. Lafont started his lectures in August 1876, Sircar and Roy in 1879. In the beginning Sircar made do with honorary lecturers although he allowed them to charge eight annas from all those who were not subscribers or substantial donors. By 1887 the Association was offering a package of lectures in physics, chemistry, mathematics and geology. The panel of lecturers included such eminent names as Sircar, Lafont, J. C. Bose and Asutosh Mukherjee, whose lectures were later printed in a memoir by the Asiatic Society. One hundred and twenty-four lectures were delivered that year and publicized in newspapers such as the *Hindu Patriot*, the *Indian Mirror* and the *Bengalee*. One interesting feature was the presence of women in the audience, especially from Calcutta Medical College and a larger section from Bethune College, chaperoned by Chandramukhi Bose, the superintendent. The annual report states that six practical chemistry classes were conducted especially for them. 'They were taught tests for oxygen, ozone, hydrogen, nitrogen, carbon, chlorine, iodine, fluorine, lead, silver, mercurous and mercuric salts'. (Sircar, IACS, Annual Report, 1888, p. 3.)

In the meanwhile Sircar began his fund raising efforts to expand the facilities of the Association. The first thing he did was to buy from the government the building in which the association was tentatively located. This became the lecture theatre. Next, he attempted to obtain instruments for research and a laboratory to house these instruments. Babu Kali Kissen Tagore provided Rs 25,000 for instruments, and an unsolicited grant of Rs 50,000 from the Maharajah of Vizianagram met the entire cost of the laboratory. Eugene Lafont, returning after his convalescence in France, brought back an entire set of instruments to illustrate the lectures on thermionics, acoustics and optics. Some of these instruments, like the sympatograph and the catellets machine for the liquefaction of oxygen, were introduced into India for the first time. (Sen, 1976, p. 15.) But while Sircar was successful in providing buildings for a lecture theatre and a laboratory, he realized it was not enough. This was merely the outer shell of science, but what was essential was a cadre of professional scientists in the pursuit of original research. In attempting to create this he failed. He tried to institute three professorships in the names of David Hare, Lord Ripon and Queen Victoria. Apart from a few initial subscriptions by the Nawabs of Dharbhanga and

Salarjang, the drive met with little success. But while Sircar despaired of the Association ever pursuing active research in science, the teaching activities of the Association acquired a new impetus. The Association became affiliated to the physics and chemistry departments of Calcutta University. The private colleges of that time lacked the necessary equipment for teaching science courses at the B.Sc. level. Sircar was not initially enthusiastic about the move and it was Lafont who realized its importance. Lafont emphasized that the diffusion of knowledge was one of the objectives of the Association, even if a subordinate one. He persuaded Sircar who then presented an argument for combining teaching and research in one institution.

Those, who think we are degrading the Association into a school forget that the world's chief and greatest discoveries have been made by those who had or have to teach. Nothing, in my humble opinion, enables a man to learn as well and as thoroughly as the necessity to teach. We become acquainted with the weak points of our knowledge when we have to impart that knowledge to others. In experimental sciences this is almost the case at every step. In practical teaching how often has it not happened that the difficulties experienced by students in understanding a particular subject, when duly communicated to the teacher, have led to some modification of the experiments which have been starting points of fresh discoveries? (Sircar, 1900, p. 17.)

Sircar was careful to add that education as the primary activity of the Association would cease once the colleges 'wake up to their responsibility of providing their pupils with suitable laboratories for elementary science teaching, and then its only *raison l'être*, will be the advancement of science through original research'. (Sircar, 1900, p. 18.)

Sircar's dreams of the pursuit of science through original research never came true in his own lifetime. By 1902 he lay ill, disillusioned and dying. In his annual address to the Association he remarked:

Believing that this annual meeting of our Association is in all probability the last that will be held in my lifetime, I have made a supreme effort to overcome my physical weakness in order that I may have the pleasure of meeting you this evening. But this pleasure is not unalloyed. It is mingled with intense sadness. The cooperation that you have accorded me has not enabled me to endow even a single professorship. . . . And I am forced to confess that I made a mistake in starting the project of founding a Science

Association at all, and that I have wasted a life as I have told you, in attempting to make it a national institution. If I had vigorously applied myself to the practice of my profession, though homoeopathic, I am sure I could have left as a legacy an amount of money equal to that I have succeeded in collecting in over thirty years. (Sircar, 1902, pp. 17-20.)

The final irony came when J. N. Tata, the industrialist, announced a magnificent donation towards the establishment of the Indian Institute of Science at Bangalore. Sircar hailed the proposed establishment of the Institute and yet his speech was tinged with sadness:

It is now for you my countrymen to determine what you are to do with the Science Association. . . . It cannot continue without endowed professorships. But somehow or the other I have not been able to convince you of its necessity, and the result is, while we were sleeping on our oars, a sister presidency has startled the country by what appears to be a new scheme involving an outlay calculated to tax the resources of an empire. (Sircar, IACS, Annual Report, 1899, p. 25.)

If Sircar had lived even a few years more he would have seen his dreams come true. In 1906 his son Amrit Lal Sircar argued that since the endowment fund was not adequate for a professorship, it should be used to endow two or three studentships. Sircar observed with great pride that there was already a young student working on physical optics, while obtaining his livelihood at the finance department. Amrit Lal quoted his father as remarking in his inaugural address to the Association: 'It was the boast of Count Rumford, founder of the Royal Institution of London, that his greatest discovery was the discovery of Davy and Davy in turn might have boasted that the greatest of his discoveries was the discovery of Faraday. I do not despair of such discoveries here in the future, though the future may be remote indeed' (Sircar, 1907, p. 36). The prescient Amrit Lal declared that the prophecy of his father was 'now going to be fulfilled and if circumstances do not go against us, Mr Raman will prove to be the brightest ornament of the Association.' (Sircar, 1907, p. 37.)

One of the reasons for the early problems of the Indian Association, apart from the niggardliness of the rich Indian, was the acrimonious controversy that surrounded the establishment and the early development of the institution. The debate centered on whether the Association was to be an association for science

alone or also for technical education and entrepreneurship. The debate, which was well publicized in newspapers like the *Hindu Patriot* and the *Statesman*, reveals the first attempts to create links between nationalist science and nationalist industry, the first tenuous connections between economic and cultural nationalism. It anticipates in broad outlines the later debates on industrial research in India.

The Indian Association for the Cultivation of Science was established with a great deal of fanfare. 'The initial inauguration, the support of the landed aristocracy, their subscription to its membership, the golden names of its patrons led to premature demands from the community.' They looked upon the Association as the goose that refused to lay golden eggs. The *Statesman* for example, felt 'the pursuit of science for itself would become little better than a pastime, and, [science] losing its present practical bent, would be diverted, as in the past, to abstract inquiries, or to visionary objects like the philosopher's stone or the elixir vitae.' (IACS, Annual Report, 1891, Appendix p. xxix.)

The controversy came to a head as early as the third meeting of the proposed Association in the senate room of Calcutta University. The Indian League, a semi-political association, was advocating the need for technical education and vigorous entrepreneurship to stem the growing unemployment among university graduates. The League suggested the establishment of a series of technical schools modelled on the German *Technischen Hochschulen*. The representatives of the League held that their scheme for technical education should be incorporated into Sircar's proposals for scientific instruction and research. Such a hybrid would go beyond Sircar's ideals in providing not only instruction in science but training in the mechanical arts which would open new ways of living for the people. Sircar and his colleagues opposed the suggestions of the league. The chairman of the meeting, Richard Temple, then Lieutenant-Governor of Bengal, after hearing the various shades of opinion declared that the two schemes should stay separate. But the debate was to dog Sircar throughout his life. It is necessary to understand Sircar's arguments in detail for it was later to be championed by scientists like Raman and Krishnan, in fact by the entire Indian school of physics which grew up in the thirties at the Cultivation of Science Laboratory. Sircar stated that the objectives of the Association

did not deny the complementarity of science and technology. The Association was established to enable Indians to cultivate science in all its departments with a view to the advancement of original research and its varied application to the arts and comforts of life. But Sircar insisted on the priority of science over technology. To prove his point he cited the case of science in Britain as a historical example. Authorities like George Bagehot Ferguson contrasted the enthusiasm of the wealthy classes for science in Germany with the indifference manifested by those in England. It was this anti-science spirit that prevented the development of industry in England. 'To what other cause can we ascribe the fact that although the aniline dyes were discovered in 1858 by an Englishman, Dr W. H. Perkin, yet almost the whole of the manufacture is now carried on in Germany. One company, the BASF, employs 146 chemists, 75 civil engineers, 6300 workmen in one alone of its three factories' (Sircar, 1901, p. 23). Turning then to the indigenous efforts at industry Sircar remarked, 'In our country several industries such as glass-making and match manufacture have been started without a single scientific man in any of them to guide and control their operations and with what result? What but absolute failure.' (Sircar, 1901, p. 23.)

Sircar did not deny the importance of the technical education movement of his time. What he questioned was its maturity. 'Those who have carefully considered the avowed object with which this Association was established, must have seen that not only purely scientific but technical education was embraced in its wide scope. The management of the Association has not hitherto been able to direct attention to the latter for the simple reason that preliminary scientific education must precede technical education, and before making provision to establish the former on a secure basis, it would be madness to waste energy and fritter away funds for the mere name of technical education' (Sircar, 1888, pp. 17-18). Sircar cited the recommendation of the British Royal Commission on Technical Education which stated that 'if instruction [in technical schools] is to be really useful, it must be as thorough and as scientific as possible. The indifferent technical school will soon be found out and deserted. If this is likely to be the case in England what must it be here in India? The fact is, scientific education must permeate the country before technical education is even possible' (Sircar, 1888, p. 18). The technical

education movement, he held, was merely an imitative one, whose spasmodic efforts only aped the more serious efforts in England without being sensitive to the difference between the two systems.

Sircar clinched his argument by justifying the priority of science over technology even on purely nationalist ground. He argued that science had revolutionized the relations between nations. In this new struggle for the survival of the fittest, more bitter than even Darwin visualized, an unscientific culture was an obsolescent one. He held 'that the struggle for existence is becoming harder and harder and competition is necessarily becoming keener. So that there is danger of losing not only prestige but the very chance of existence unless pace is kept with the progress made' (Sircar, 1901, p. 27). Sircar cited William Crooke's speech about the Malthusian spectre of starvation, of the wheat producing capacity of the world getting exhausted compared to the rate of increase of population. Crooke pointed a way out of the colossal dilemma. 'It is the chemist who must come to the rescue of threatened communities. It is through the laboratory that starvation may be eventually turned to plenty.' (Sircar, 1901, p. 27.)

Sircar went beyond merely establishing the priority of science over technology. He also tried to examine the complexity of their relationships, the difficulty of transforming a scientific idea into a technologically and commercially feasible product. The *Hindu Patriot*, which backed Sircar, remarked 'that between scientific knowledge and its application to the practical pursuit of these industries in India, there is a great gulf fixed, and this gulf is due to conditions which mere science is powerless to remove, which are indeed the despair alike of Savant and Statesman. In the vast majority of cases, the application of science to industry or art is not a simple operation which can be performed either by the man of science or the man of practice, even by both together, but an extremely difficult operation in which success implies long patient and costly experiment' . . . (Report, 1891, Appendix, p. xxv). He felt that 'the Science Association with its capital of Rs 88,000 in securities, could not undertake the entrepreneurial function, for pioneers who undertake such enterprise must generally be prepared to undergo heavy and sustained risk which the association could ill afford.' (IACS, Annual Report, 1891, Appendix p. xxv.)

But Sircar's arguments against what he dubbed as illtimed pleas

of relevance were in vain. As his son Amrit Lal remarked, he often wished that the word 'applied science' had not been invented. Amrit Lal Sircar, speaking of his father's refutations against accusations of irrelevance, observed,

There have been men at all times and at all ages who have not had the opportunity to look into the subject deeply and consequently they think that science is of doubtful value altogether and the world would be just as well off without it. Their cry is for Industry and to show their contempt for pure science they have invented the meaningless phrase 'applied science', which alone in their opinion is a useful branch of knowledge. Without the attempt to answer in any words of my own, I would simply quote what Professor Huxley said with reference to this misleading term 'applied science'—'I often wish it had never been invented for it suggests that there is a sort of scientific knowledge of direct practical use which can be studied apart from another sort of scientific knowledge, which is of no practical utility and which is termed "pure science". But there is no more complete fallacy than this. What people call "applied science" is nothing but the application of science to practical classes of problems.' (Sircar, 1905, pp. 21-2.)

Mahender Lal Sircar's dream of an association combining the functions of teaching and research was to be eventually realized in the University College of Science in 1916. In the following section we shall analyse the forces that led to it.

The stunted development of scientific research in India was not the preoccupation of the Indian intelligentsia alone. Alfred Pedler, Professor of Chemistry at Presidency College, Calcutta devoted his presidential address to the Asiatic Society in 1896 to it. (Pedler, 1896.) Pedler chastized the Society for being too preoccupied with the preservation of oriental manuscripts. He felt that the Asiatic Society, along with the government, must embark on a vigorous programme to encourage the natural sciences. Pedler admitted that the state had established departments pertaining to botany, geology and meteorology, but they were basically concerned with routine research. In his address Pedler offered an interesting but truncated table (Table 2-1) regarding the publication patterns of the Asiatic Society. The table is divided into spans of ten years and classified into two subjects, literary and scientific. The table further indicates whether the authors are Indians or foreigners. (Pedler, 1896, pp. 12-13.) 'The figures present some

remarkable features. Between the period 1836-95 the Society seems to have been more active than in any of the subsequent periods.' Pedler points out however that 'the figures are misleading for most of the earlier papers were short notes, more descriptions of fact and phenomena of comparatively little importance.'

TABLE 2.1
Publication Pattern of Asiatic Society

Period	Total No of Papers	Litere- rary (Part I)	Scien- tific (Part II)	Part I		Part II	
				No. of papers by Euro- peans	Natives	No. of papers by Euro- peans	Natives
1836-45	684	275	409	273	2	406	3
1856-65	231	119	110	105	14	110	0
1866-75	436	160	187	131	29	186	1
1876-85	389	147	164	115	32	164	0
1886-95	355	128	169	100	28	155	14

The papers reflected no long and sustained research. The sudden decrease in the number of papers between 1856-65 was due to the war of 1857. Otherwise the number of publications was fairly constant. It is the later half of the table that is more interesting. Pedler compares the number of contributions made by Indians and Europeans. Considering the literary section first, Pedler points out

between 1836-45 only two out of the 275 papers were by native gentlemen, less than 1%. In the decade 1856-65 contributions by Indians had risen to 12%, in the following decade to 18%, by 1886-95 to 22% of the total contributions. But it is the figures showing the proportion of contributions in science that are the most dismal. In 1836-45 Indians contributed 3 out of 409 printed. In the decades 1856-65 and 1876-85 there was not a single paper by Indians to the natural science section although 110 and 164 papers were presented during this period. An improvement is however noticeable in the last period 1886-95, for out of the total number of 169 papers, 14 papers were written by native gentlemen, about 8% of the number. (Pedler, 1896, p. 13.)

On further analysis Pedler found out that authorship of these 14 papers could be traced to three individuals and, again, that all the researches were devoted to mathematics. He concluded on the

basis of his analysis that 'natives' as a whole had not shown any particular aptitude for original research in the physical and natural sciences. Pedler's solution to the problem was the creation of more fellowships, like the Premchand Roychand Scholarship and Elliot Prize of the Asiatic Society, and he called on Indian princes and noblemen to donate generously. But the malaise of scientific education was deeper than Pedler realized. It lay in the structure of the colonial education of the time, in the inequalities of the system; in the discriminations Indians pursuing a career in academics were subject to at that time. It is best illustrated in the case of two of Pedler's own colleagues—J. C. Bose and P. C. Ray.

J. C. Bose obtained his B.A. from St Xavier's College, Calcutta, where Eugene Lafont was one of his teachers. He went to Cambridge in 1878, worked under Rayleigh and Francis Darwin and returned in 1885 as a junior professor of physics at Presidency College. Bose's appointment met with immediate objections. Patrick Geddes, Bose's first biographer, describes the attitude of the time: 'There was a strong doubt, not to say prejudice against the capacity of an Indian to take any important position in science. Intellectual acuteness in metaphysics and the languages has been frankly acknowledged but it was assumed that India had no aptitude for the exact methods of science. For science therefore India must look to the west for teachers. This view was accepted by the government and so strongly maintained in the education department that when Bose was appointed officiating Professor of Physics in Presidency College, its Principal objected on the above grounds.' (Geddes, 1920, p. 33.)

Bose was only allowed to accept the professorship if he waived his claim to full professional salary and accepted two-thirds of it. He protested in a quiet way—by never touching his monthly cheque. Bose's colleague, P. C. Ray, faced even greater problems. After obtaining the Hope Prize fellowship and a D.Sc. from Edinburgh, Prafulla Chandra Ray returned in 1888 hopeful of an appointment in the Bengal educational department. The Educational Service, like the civil service, possessed a two-tiered structure. The imperial levels of the service were meant basically for the English and the rare Indian who crossed the threshold was only entitled to two-thirds of the salary of his English colleagues. It was the Provincial Service that catered to Indians. P. C. Ray could not find a post for a year. Eventually, he was appointed to the post

of temporary Assistant Professor at a salary of Rs 250 a month. Ray complained, contending 'if a British chemist of my qualifications were present, he would have been appointed immediately by the Secretary of State to the Imperial Service' (Ray, 1932, p. 80). Ray's protest was of no avail and he began teaching in August 1889. The achievements of Bose and Ray had an enormous impact on the nationalists of the time.

From 1885 to 1889, working in a small laboratory with only a tinsmith as mechanic, Bose initiated researches on Hertzian waves. His first paper '*The Polarization of an Electric Ray by a Crystal*' was read at the Asiatic Society. It was only when reprints of the paper reached Rayleigh and Thompson that Bose's work obtained recognition. The western world had to admit that the Indian mind had not only a speculative genius but also an unsurpassed experimental brilliance. In 1898 Bose switched his field from physics to physiology and in 1900 read a paper at the International Congress of Physics contending that it was difficult to draw a line between the physical and the physiological. The pioneering work of Bose soon attracted attention in Britain, France and Vienna.

The achievements of Bose and Ray, both ardent nationalists themselves, inspired an era. Bose's work on plant response was in fact described by the Prabasi as the greatest Swadeshi event of 1906. The achievements of Bose and Ray and the discriminations of the educational system aroused the Indian nationalists, and the Indian National Congress passed a motion against such obstacles in 1896. The pride in the scientists' achievement is obvious in the speech of Anand Mohan Bose who was steering the motion.

Why Sir, we know that the *London Times* has only the other day borne testimony to the fact that the year 1896 is an epoch making year as regards the intellectual advance of India. We know that the grand researches of an Indian professor in the field of invisible light in the sublime and giddy heights of ethereal vibrations have led to discoveries which have filled the mind of Lord Kelvin, the highest authority that England has produced, literally with wonder and admiration. We know the discoveries which also in the present year of grace have rewarded the genius and patient toils of another countryman in the realms of chemical research. The present year then, when India has shown that she has not forgotten the glorious destiny of the past, when the Indian mind has awakened to the consciousness of the great destiny before it—surely this is not the time to usher in policies of such a retrograde character. (Ray, 1932, p.155.)

The careers of Bose and Ray reflect and participate in the more innovative movements of the era. We observe also some of the first attempts to integrate cultural and economic nationalism in the achievements of these men. It is a little known fact that Bose was one of the first scientists to produce a radio receiver. Patrick Geddes accords him priority over Marconi.

As early as 1895 in a public lecture at Calcutta Bose demonstrated the ability of rays to travel from the lecture room through an intervening passage to a third room, seventy-five feet distant from the radiator, thus passing three solid walls on the way as well as the body of the Chairman (who happened to be Lieutenant-Governor). The receiver at this distance still had energy enough to make a contact, which set a bell ringing, discharged a pistol and exploded a miniature mine. To get this result from this small radiator Bose set up an apparatus which curiously anticipated the antenna of modern wireless. (Geddes, 1920, p. 62.)

But Bose strangely enough never took a patent on his own invention. In 1901 one of the outstanding wireless manufactures approached him with a lucrative contract, which he refused to sign. An American friend patented it in Bose's name but Bose refused to use his rights and allowed the patent to lapse. 'The British magazine, *Electrical Engineer*, was amazed that Bose had no secret of its construction.' (Geddes, 1920, p. 63.) As regards his own work, Bose remained a cultural nationalist. But the entrepreneurial streak was present. Bose's father, Bhagabanchandra Basu, established one of the first cooperative banks in the country. Jagdish Bose himself was involved in the technical education movement in 1906, which laid strong emphasis on entrepreneurship. But as Bose himself pointed out, the man who first combined science and technology, cultural and economic nationalism, was Prafulla Chandra Ray.

Prafulla Chandra Ray was one of the most important figures in the rise of institutionalized industrial research in India. The father of the first School of Chemistry in India, the first Indian scientist to turn entrepreneur, a great authority on ancient Hindu chemistry, he encouraged a generation of students at Presidency College, who were eventually to make a case for industrial research in India. The biography of the man reflected the historical achievements of this great era, and the philosophy of the man reflected a generation's attempt to relate science and technology to Indian Society. If Ray's pride in Indian culture was evident in his history

of Hindu chemistry, his economic nationalism was obvious in his attempt to establish the Bengal Chemicals and Pharmaceuticals Works (BCPW).

Ray realized that in the progress of western society, industry as a rule had preceded science. In the fields of soap-making, glass-making, dyeing and metallurgy the empirical operations were known long before the chemical principles were understood. He felt that what Bengal needed was not a spate of technical institutes but initiative expressed in entrepreneurs like Carnegie and Bessemer.

Bessemer who revolutionized the process of steel-making knew nothing about metallurgy but that did not daunt him. He read everything he could find on the subject. Andrew Carnegie who began his career as a telegraph operator repeats almost the same story. Carnegie was neither an inventor nor a master of science. He was in a word self-taught. But few men have been more successful in adapting a great invention to the needs of his time than was Andrew Carnegie in seizing upon the Bessemer process and using it for the expansion of American and world industry. It will thus be seen that it is not so much the possession of expert technical knowledge, but organizing capacity, resourcefulness and initiative which are essentials in the making of a businessman or a captain of industry. (Ray, 1932, p. 277.)

Ray felt that the Bengali youth of his time lacked drive, that the age of the Bengali entrepreneur was over; that the college youth seeking a soft government job had allowed himself to be replaced by the Marwari. He saw around him the need for entrepreneurship, 'to utilize the thousand and one raw products which nature in her bounty has broadcast over Bengal.' (Ray, 1932, p. 92.) While still professor at Presidency College, P. C. Ray decided to turn entrepreneur.

Ray began by attempting to extract citric acid out of lemon juice but andoned this as commercially unfeasible. He decided that, given the conditions, he must seek an industry which was small in scale, yet commercially paying, where his scientific training could be utilized. After a market study of drug houses in Calcutta, he decided on pharmaceutical operations. The future Bengal Chemical and Pharmaceutical Company began in the kitchen of Ray's house. Consulting the monumental *British Pharmacopoeia*, Ray made a number of preparations, storing them in second-hand bottles brought from the local *bikriwallahs* of Bow Bazaar. But the

problem as Ray soon realized was not the use of science to create a product. This was the first step. What he had also to do was to sell it. The travails of indigenous technology are obvious in the history of BCPW. As Ray remarked 'the local dealers in drugs were as a rule innocent of the rudimentary knowledge of chemistry. They can at best calculate the profit and loss of a transaction. They expressed their admiration for the articles offered, but shook their heads, saying, "Belayti drugs command a ready sale whereas deshi drugs would be refused by our customers."' (Ray, 1932, p. 101.) Ray and his colleagues, his classmate Amulya Charan Bose and Chandra Bhushan Bhaduri, demonstrator at Presidency College, planned a vigorous marketing strategy. Bose campaigned amongst the medical profession, seeking out the nationalist members of the profession, men like Radha Gobind Kar and Nilratan Sircar, and persuaded them to recommend concoctions made by the nascent enterprise. (Ray, 1932, p. 104.)

The innovators went further. Amulya Charan Bose was a great advocate of Ayurveda and he realized that Radha Gobind Kar shared his faith in these drugs. Amulya Charan consulted several Kavirajas and collected a number of recipes for ayurvedic preparations. He then launched a sales campaign, convincing the rest of the medical profession of the efficacy of these drugs, which had long been standard remedies in the households of Bengal. 'All that was needed was that their active principles should be extracted scientifically and they should receive the imprimatur of the practioners. Amulya Charan himself took the lead in the bodily use of these preparations.' (Ray, 1932, p. 104.) The three entrepreneurs carried their campaign even further. They pointed out that as early as 1841, W. B. O'Shaughnessy, Professor at Calcutta Medical College, and later Kanai Lal Dey, in his *Indigenous drugs of India* had advocated the substitution of some of these for the drugs officially prescribed in the *British Pharmacopeia*. In the 1898 Medical Congress Kanai Lal Dey eventually managed to urge the recognition of these drugs by the *British Pharmacopoeia*—it was added reluctantly in an addendum. It was also at this Medical Congress that Ray displayed his indigenous drugs at a special stall. In 1901 the works was converted into a limited liability company with Ray and Bhaduri as Directors. John Cummings, in his review of the industrial position and prospects of Bengal (1908), described it thus:

The BCPW is one of the most go ahead young enterprises in Bengal. Dr Prafulla Chandra Ray, B.Sc., F.C.S started it as a small private concern in Upper Circular Road about 15 years ago and made drugs from indigenous materials. About 6 years ago it was made into a limited liability company with a capital of 2 lakhs. Many of the leading chemists of Calcutta are shareholders. It is now a well thought out and well managed factory with about 70 workmen. Babu Rajsekhar Bose the manager is an M.A. in Chemistry. The variety of manufactures of laboratory apparatus, which requires skilled craftsmen in wood and metal has been taken up. The latest development is in perfumes. The enterprise shows signs of resourcefulness and business capacity which should be an object lesson to capitalists of this province. (Ray, 1932, p. 111.)

The innovations of Mahender Lal Sircar, P. C. Ray and Bose were all reactions against the state of Bengali society at that time. The failure of the anglicized intelligentsia to obtain employment had started off a whole spate of entrepreneurial movements. It is precisely at this time that we see a pre-occupation not only with the Indian past but with the future of Indian industry. The works of R. C. Dutt, Dadabhai Naoroji and Ranade were published at this time. The gospel of Swadeshi had come into being. Simultaneously, English education had produced a powerful reaction which demanded a return to the vernacular. Rabindranath Tagore saw in the alienation of the intelligentsia from the masses the fundamental problem of the time; he advocated the use of traditional folk media like the mela and the jatra along with modern instruments like electric lanterns to spread education among the masses. P. C. Ray, troubled over the poverty of Bengali scientific literature, began writing a number of primers in chemistry, botany and geology. Gooroodas Bannerjee, already associated with Sircar's 'Cultivation of Science', referred to the malaise of science in Calcutta University. (Sarkar, 1973, p. 152.) In his convocation addresses he suggested the use of the mother tongue, university fellowships for the promotion of original research and provisions for technical education. The failure of the anglicized university and its creation of a whole series of parasitic professions bothered not merely the Indian intelligentsia but the Viceroy, Lord Curzon. Curzon realized that Macaulay's attempt to anglicize India was a disaster. By making English education the key to government employment it had made examinations the sole criterion of worth. He also felt that the anglicization of the elite

had given it a taste for political control, and Curzon was afraid that the élite would manipulate the masses. He thus sought to limit the growth of this group and encourage vernacular education. The 1902 conference that Curzon commissioned demanded the reconstruction of university senates, the transformation of the university from an examining to a teaching institution and strict control over affiliated colleges. But Curzon's attempts to restrict university education and institute government control over the university met with protest. This protest channelized itself after the Partition of Bengal into the National Education Movement of 1905.

The National Education Movement of 1905 was part of the Swadeshi movement of the time, bringing about a synchronic efflorescence of ideas on a broad series of fronts. On the economic front, the Swadeshi movement demanded a boycott of British goods and support for indigenous industry. On the political side it realized the necessity of emphasizing that British and Indian interests were no longer compatible. On the educational front there was a realization that anglicized culture alienated one not only from the masses but from 'national culture'. The boycott of British goods was soon followed by the boycott of Calcutta University. The agitation of students and the summary dismissal of those who participated led the leaders of the movement to think of alternatives in education.

The Nationalist Education Movement soon split into two camps. One group demanded the renaissance of an entire culture; its leaders, Goorodas Bannerjee, Satish Chandra Mukherjee and Tagore advocated a complete, parallel structure of national education under national control. Discarding the extremism of these cultural nationalists were a group of moderates led by Tarak Nath Palit and Nilratan Sircar. These men merely wished to inject courses in scientific and technical education into the literary bias of the university. The difference between the leaders led to two separate institutions—the National Council of Education and the Society for the Promotion of Technical Education. But neither the bread and butter philosophy of the Bengal Technical Institute nor the patriotism and Swadeshi of the National Council attracted the students of Bengal. The initiative passed back to the conservative corridors of Calcutta University. The National Council of Education eventually became the Jadavpur University of today. The

Technical Institute was to become the basis for the University College of Science.

In 1906 Lord Minto the new Viceroy requested Asutosh Mukherjee to accept the Vice-Chancellorship of Calcutta University. Asutosh Mukherjee believed that many of the changes demanded by the nationalist movement could be obtained within the framework of the existing universities. He wanted to fully institutionalize the provisions of the University Act of 1904 which made it possible for the first time to combine the functions of teaching and research. Mukherjee was influenced by the German universities of the time. These institutions possessed two admirable characteristics: the effectiveness with which they combined teaching and research, and the professional specialization that went with it. As an active member of the Asiatic Society of Bengal, he had observed how German specialists had displaced British scholarship in the field of Indology. While the nationalist movement was in full swing, Asutosh Mukherjee proceeded to reform Calcutta University within the framework of the new Act. Attempting to transform Calcutta University into a teaching institution, Mukherjee instituted an examining committee to inspect colleges and only those that conformed to his stringent standards were affiliated. While Mukherjee was skeptical about the nationalist movement, he was aware of the debates within it. Rabindranath Tagore, P. C. Ray and Goorodas Bannerjee, the University's first Vice-Chancellor, were advocating the use of the vernacular in undergraduate courses. But Mukherjee remained an anglicist at heart convinced of the power of the English language and western science. In 1909 he declared that, 'English knowledge should be brought home to our students through the medium of English, that Western light should reach us through Western gates and not through the lattice work in Eastern windows'. However, he did provide for a compulsory paper in the vernacular at the undergraduate level. After completing reforms relating to undergraduate education, Asutosh Mukherjee turned his attention to postgraduate education, to the need for an institution combining teaching and research.

It was at this time that Taraknath Palit, disheartened by his efforts to provide for technical education under the nationalist banner, handed over the assets of the Bengal Technical Institute, to Calcutta University. By October 1912, Mukherjee had received

two donations; one for Rs 14 lakhs from Tarak Nath Palit and one for Rs 10 lakhs from Rash Behari Ghosh. This enabled him to provide for two professorships in physics, two in chemistry, and one each in botany and applied mathematics. All these grants allowed Asutosh Mukherjee to establish the University College of Science. By 1922 the University had received Rs 40 lakhs from private sources for the pursuit of science.

The University College of Science was a unique institution. The significance of its formation lay in the fact that it was here, for the first time since the establishment of the universities in the fifties of the nineteenth century, that higher science teaching in all its branches was taken up seriously as a part of its regular functions, and that the advancement of knowledge by scientific research was recognized as one of the prime duties of the teacher. The Palit Professorships in chemistry and physics were the first two university chairs in science to be founded in India. One of the conditions imposed by the donors was that all chairs founded from their benefactions should be exclusively held by Indians. The significance of this will be appreciated from the fact that, at the time the benefactions were made, Indians were practically barred from entry into the higher educational services of the government.

The University College of Science had on its faculty some of the greatest scientists of the time. It had Raman and Ray as the first Palit Professors. Asutosh Mukherjee also recruited a group of young scientists—J. C. Ghosh, M. N. Saha, J. N. Mukherjee, S. N. Bose—as lecturers. These young scientists were to play a crucial role in the development of industrial research in India. This group, many of whom worked under P. C. Ray, went on to initiate attempts to link science and industry. They were to be the outstanding exponents of planning and heavy industrialization in India. But strangely, the man who sired them, P. C. Ray, the first Indian to establish a science-based industry in India, who once saw sulphuric acid as an index of industrial progress, turned his back on heavy industry and became the leading advocate of Khadi. The explanation is best reconstructed from his own writings:

Ever since my college days in the eighties of the last century I have been a devoted student of Western Science and I have tried my best to divert science to practical application. It has been my privilege to be instrumental in introducing in Bengal at least one aspect of science. Close

upon a century ago, the great experimental chemist Liebig laid down that the index of the civilization of a country is the amount of soap it consumed and he further asserted that the industrial progress of a country was measured by the output of its sulphuric acid. And it so happens that I am intimately associated with several concerns—one which manufactures soap in large quantities and another, BCPW, which bids fair to be the biggest producer of India of sulphuric acid and its accessory products. When Mahatmaji in 1921 first made the Charkha the symbol of the new movement, I myself, a staunch believer in mechanization, laughed at this relic of medievalism. (Ray, 1962, pp. 88–9.)

But soon Ray directed a whole series of flood and relief operations in Bengal and it is then that he felt

the supreme need for jobs for the teeming millions of India during the non-crop seasons . . . India is an agricultural country and must ever remain so. The problem is how to increase the productivity of agriculture by improving productivity of the soil and how to supplement the scarcity of income of the dwellers in the villages by subsidiary occupations. I hold that spinning and weaving are two parts of one cottage industry which admits universal application (Ray, 1962, p. 88). Of the Bombay Cotton Mills at best they gave employment to 3 or 4 lakhs as do the jute mills of Hooghli. At the most 2 millions earn their bread in the industrial centres of India, but what of the remaining 318 million? Will you wait till Manchesters, Liverpools, Glasgows and Dundees spring up here and transfer 70% of the rural population to urban areas. Are you going to industrialize India? With the exceptions of Calcutta and Howrah there are no towns in Bengal. The district towns are towns only in name; they are localities where law courts have sprung up and they support a parasitic population. I am afraid you will have to wait till doomsday. (Ray, 1932, p. 89.)

Ray differentiated between the Swadeshi movement and the Gandhian movement with reference to the charkha. 'In the days of the former we threatened to go back to the charkha to be satisfied with coarse cloth rather than try foreign cloth. In the end we relied on the mills of Bombay' (Ray, 1962, p. 84). But the Gandhian charkha, he maintained, was a totally different solution. The former was purely a weapon to achieve political rights. The latter was based on love, 'love for those who wield the tool and also for those against whom the tool is utilized. Gandhi holds before the Britishers the example of the India of his imagination, the India of his idealism, and asks the world to look at her and benefit by it. He asks the militant world to live and let live. (Ray, 1962, p. 89.)

Apart from the earning potentiality of the spinning wheel Ray was satisfied with the distribution of money it earned.

The problem of distribution is not a whit less important than the problem of production; what do we gain if millions of our countrymen starve while a few fatten on unnatural gains? Only inequality in wealth will be created, the spectre of hunger and employment will stare us in the face in an uglier form, and class war of dimensions most appalling will inevitably ensue. I need not be understood as saying all big scale industries should be smashed. The thing cannot be disposed away so airily—I could not even if I would. But surely you will agree with me that if the same result can be brought about by means much less harmful, surely that is preferable. An easy, healthy, natural process of increasing the wealth of the country and smooth way of universalizing the incidence of wealth,—that is what the Charkha represents. (Ray, 1962, p. 89.)

The Durkheimian vision of Ray was to meet its strongest objection among his own proteges. The twenty years of the Science and Culture group under Saha represented the alternative vision of planning, heavy industrialization and big science and owed inspiration not to the Gandhian impulse but to World War I and the Bolshevik Revolution. We shall explore this in the fourth chapter. Mediating between the two is the colonial government's own efforts to rationalize science and technology in India. This is embodied in the Industrial Commission Report of 1918. It is to this that we shall turn in the next chapter.

CHAPTER 3

THE RISE OF INDUSTRIAL RESEARCH II

I

The failure of the Swadeshi movement brought in its aftermath a spate of self criticism. Outstanding in this area were the contributions of Gandhi and Ananda Coomaraswamy. Both offered a critique of industry embedded within a notion of civilization, yet both remained eccentric or marginal to the scientific establishment.

Ananda Coomaraswamy was a professional geologist. As Director of mineralogical research in Ceylon, he was responsible for the discovery of its thorium deposits. It was during his extended field trips in Ceylon that Coomaraswamy became aware of the decline of the craft traditions under colonialism, a sensitivity which he articulated into a life long advocacy of Indian civilization. For Coomaraswamy, colonialism and industrialism were gross acts of philistinism antithetical to the native genius in art, architecture and music. He sought to evaluate the social movements of his time on the touchstone of this traditional aesthetics.

Coomaraswamy had no quarrel with the formal objectives of the Swadeshi movement, its professed efforts to check the drain of capital through the production of goods hitherto imported. But he felt a mere act of displacement or substitution was not enough. It had to be accompanied by a theory of what goods one ought to have and how they were to be produced. It was here that Coomaraswamy faulted Swadeshi. He perceived it as unimaginative and impelled by a dull commercial prosperity. He saw in this commercialism the subversion of the movement and counterposed to this commercial Swadeshi, a higher Swadeshi which demanded a return to the traditional aesthetics embodied in the craft traditions. Coomaraswamy saw the current phase of Swadeshi as indifferent to this.

What has Swadeshism done for Indian art? Almost nothing; when a decaying industry can be used to political advantage it gives it loud support, and in this way the handloom industry of Bengal is receiving attention now; but the whole country from north to south is full of decaying industries and perishing hereditary skill, to save which no effort is made. Efforts are being made to establish all sorts of factories for making soap, matches, cotton, nibs, biscuits, and what not, while men, men who can still weave, still work with gold, silver, copper, wood and stone are starving because their work is out of fashion. Swadeshism often ignores things which India has from time immemorial made perfectly, to seek to manufacture things which it would be better to do without altogether, or frankly to buy from nations more able to make them easily. (Coomaraswamy, 1909, pp. 73-4.)

If Coomaraswamy sought through Swadeshi to preserve the continuity of tradition, Gandhi innovated within the traditional discourse to provide a critique of modernity.

Gandhi's theory encompassed the nationalism of Swadeshi into a wider civilizational discourse on Swaraj. He argued that the political conception of Swadeshi was either punitive or imitative. While his compatriots saw in Japan the embodiment of the Swadeshi dream, Gandhi perceived in it a Fordist nightmare involving the virtual Americanization of a culture. He dismissed the model farms of Sir Gangaram and Tata's steel works as well intentioned but irrelevant exercises and sought to restore the Swadeshi notion of technology back to its roots in the native cosmos. For him it was a religious discipline where 'the deprivation of a pin or needle, because they were not manufactured in India, need cause no terror.' (Hingorani, 1966, p. 68.) Gandhi's theory of the *charkha* has to be understood in this context. It embodied participation, an empathy with and a panacea for the sufferings of village India. But the semiotics of Gandhian technology proved elusive to the scientific establishment wedded to the idea of technological progress. Eventually, it was Swadeshism, as import substitution, the gradual displacement of foreign goods and personnel by their Indian equivalents, that acquired the colonial imprimatur. It is this translation of Swadeshism into the grammar of official technological discourse that must be explored. The key text for this exegetical act is the Industrial Commission Report of 1918.

II

One of the ironies of history is that war has always been an instrument of technological progress. Desmond Bernal in his *Social Function of Science* went to the extent of contending that almost all the significant inventions of history have their roots in military requirements of some form or other. He attributed it to the exigencies of war where a change of technique has all too often spelt the difference between victory and destruction. (Bernal, 1967, p. 165.) But even within such a historical framework as posited by Bernal, World War I was a unique event. It transformed the relation between science and the state, which was till then an ad hoc one activated only in times of crises, into an institutionalized one, rationalizing and routinizing the relationship. As a consequence of the shortages and scarcities of World War I, the governments of the U.S.A. and the Britain realized the essential symbiosis between science and technology and made conscious efforts to integrate them. This resulted in the establishment of the Department of Scientific and Industrial Research in 1916 in Britain and the National Research Council by President Wilson in 1921.

World War I also brought into focus the problems of Indian industry. The War revealed the dependence of the country on external sources for many commodities. The railway system was dislocated as a result of a shortage of materials; supplies of dyes, medicines and other chemicals also became scarce. As a result of these experiences the government resolved to examine the question of a new industrial policy and in a despatch to the Secretary of State in 1915, the Government of India argued that 'after the War, India will consider herself entitled to the utmost help the government can afford in order to enable her to take her rightful place as far as circumstances permit as a manufacturing nation.' (Saha, 1940 (1), p. 501.) One consequence of this was the establishment of the Indian Industrial Commission of 1916.

The Commission was convened under the chairmanship of Thomas Henry Holland and included the following members: Alfred Chatterton, F. H. Stewart, Madan Mohan Malaviya, Dorabji Tata, C. E. Low and Fazulbhoy Currimbhoy Ebrahim. The recommendations of the Commission, which included a note

of dissent by Malaviya, were submitted in 1918.¹

The seven volumes of the Industrial Commission Report along with the journal *Science and Culture*, constitute the two most important texts in the archives of Science Policy in India since 1900. Strangely, the reports of the Commission have never been systematically considered in the histories of science and technology. It is true that its recommendations were never accepted; yet defeated documents often contribute to the content of later victories. Viewed as discourse, the Reports remain one of the most systematic attempts to outline the making of an industrial society, a complete grid on which all the later debates on science and technology may be plotted. It is this act of mapping that we shall explore.

Viewed in this way, the discourse can be read at three levels. First, the Report was an attempt to mediate a fundamental discontinuity. It was an official recognition of the need to transform India from an agricultural to an industrial society. It begins with a fascinating post-mortem of the Swadeshi movement as an attempt to indigenize science and technology as activities. The Commission's ruthless cross-examination of the Swadeshi movement stripped it of its rhetoric and what remained was a cold blooded analysis of the organizational requirements of an industrial society. Supplementing the examination of the Swadeshi effort were descriptions of the efforts of British officials in initiating new industries. Implicit in all this was an intuitive and occasionally uncomprehending apprehension of the role of the modern state in the technological process. Presented eventually was a picture of the colonial state as a pedagogue, socializing its colony into an industrial way of life, training Indian personnel to occupy the secondary tiers of the bureaucracy. The concept of industrialization elaborated was one which emphasized the necessity of thinking of an industrial society as a structure of organizations.

The second level of the discourse was an attempt to understand the role of science in mediating the transition from plantocracy to technocracy. At this level the Commission's investigations were a

¹The Commission's Report comprises seven volumes. The Report proper is hereafter referred to as (ICOM. Report) and the minutes of evidence, which are in five volumes, as (ICOM. Minutes); the appendix as (ICOM. Appendix).

stocktaking of the imperial contribution to science in India. It confronted issues regarding the location and nature of scientific activity. The imperial question was whether or not scientific activity could be progressively located in India and performed by Indians. A second set of issues dealt with the nature of the organization, as to whether the administration of these activities was to be a central or local portfolio. The problem in administration became resolved into an act of classification, determining whether the scientific services were to be organized vertically in terms of natural disciplines or horizontally in terms of the functions to be performed. Outlined eventually is a conception of a rationalized scientific service.

The third level of the discourse sought to work out the relation of science and technology in the industrial process. Centering around an examination of the Indian Institute of Science, Bangalore it provides some of the first concrete efforts to plan for an industrial research laboratory. Unfortunately, while the various species of industrial research from metallurgy to leather are sketched out, the industrial research laboratory as a reality *sui generis* remained elusive. One can however discern attempts to conceive of scienticized technology as a network of linkages between the still nascent aspects of an innovation chain.

The three levels eventually culminate in the recommendations of the Report. It is this that prompted Madan Mohan Malaviya's famous note of dissent. Malaviya's note, a detailed recovery of history, was a critique of some of the fundamental assumptions of the Report. Unfortunately, it is often perceived as an entity apart from the rest of the Report. It will be argued that Malaviya's note, along with his innumerable cross-examinations, constitutes an intrinsic part of the Report. Each level of the discourse will now be described.

III

At an overt level, the attitude of the British officers to the Swadeshi enterprise reflects the usual colonial stereotypes. Archetypical of this attitude is the testimony of Francis Spring, Chairman of the Port Trust at Madras. The British engineer believed that Swadeshism was inherently futile because its mandarin elite devalued technical competence. 'Who goes to our

engineering colleges here? Not those who hope to be lawyers but young men who do not see much prospect of succeeding in law' (ICOM. Minutes, Vol. 3. p. 73). On being told that there was a general desire among Indians for more to be spent on technical education, Spring retorted, 'In token of this desire, will one of them stand up in the legislative council and suggest that ten lakhs be cut off from the Presidency College grant and given to the Madras Engineering College?' (ICOM. Minutes, Vol. 3, p. 74.)

Spring saw the entire movement as flawed. Its scale of technology was misconceived, the climate of entrepreneurship totally lacking. The imperious engineer eventually concluded that 'there was something lacking in the soul of the Indian people taken in the lump, viz. the intense internal desire for accuracy' as is implanted in the Occidental race. (ICOM. Minutes, Vol. 3. p. 74.)

For Spring, industry was a text over which Indians lacked mastery. In fact, he reduced it to the internalization of a three dimensional drawing. Indian craftsmen, he claimed, could only draw in two dimensions. In an eloquent statement, Spring explained the importance of drawing. 'By the use of the term I desire to convey the following idea. Drawing is a means whereby even if all the machines were destroyed, and not one of them was left, but only a set of drawings of them, and if after ten thousand years, these drawings were dug out, our successors should be able to repeat these machines. That is what I call drawing. (ICOM. Minutes, Vol. 3, p. 66.)

In the idiom of these British officers, technological incompetence was a reflection of moral temper. In fact, Victorian moralism and the technological imperative combine to provide a new idiom for colonial domination. Alfred Chatterton restates the white man's burden when he remarked, 'When India can do her own engineering work, then and only then will she be able to govern herself' (Chatterton, 1912, p. 359). The colony was thus transformed into a school, with a paternalistic parent ushering her progeny into technological adulthood. W. S. Hamilton remarked in his testimony before the Commission,

There is little pride in doing work as thoroughly and as quickly as it can be done but there is everywhere patent dishonesty in not working to sample, in not devoting time that has been paid for, in saving a shameful pice by misplaced putty. . . . The rickety chairs, the misshapen keys, the shoddy lungis, all find their source in this moral defect. . . . These moral defects

make Indian labour expensive though it is low paid; but we hope to eradicate it with a suitable system of education. It can be done by instilling method, by inculcating concentrated attention, by rewarding exactitude and honesty, and punishing scamping; by insisting on perfection in lower details before passing on to the higher, by teaching each boy to use his will as his hand, by showing through payment or promotion that good work pays. (ICOM. Minutes, Vol. 5, p. 91.)

The protagonists of Swadeshi were not inherently against the missionary moralism or the managerial incentives of the Commission. Their challenge was more fundamental. The argument is captured in Malaviya's innumerable cross-examinations which crystallized into his famous note. Malaviya questioned the view that it was the west that had provided the great traditions of technology. Such a statement, he remarked, denied the long history of Indian achievements in ship-building, smelting, weaving, etc. But more importantly what Malaviya was questioning was the very appropriation of discourse, that industry as text was a western monopoly. Such a view, he argued, posited an ontology with grave consequences. Apart from denigrating the continuous history of technological achievement in India, it posited a false history of industrialism in the west. By creating a false theory of industrialism, it could create a new administrative space, a boundedness which reduced Swadeshim to a failure of professionalism, a problem in manpower planning. Such a view paid no attention to political issues. Malaviya noted that the fiscal autonomy of India was beyond the purview of the Commission and quoted Nicholson's observation that 'that part of Hamlet had been left out'. Malaviya suggested that a recovery of history must parallel a recovery of industry in India. He argued that the de-industrialization of India and the history of the industrial revolution in the west were integral parts of one process, that colonialism preceded and helped create industrialism in Britain.

Malaviya's note has been embedded for too long in the archival monuments of nationalism. But its power stems not from the rhetoric of the de-industrialization thesis, but from its insistence that the Commission's understanding of industry was eclectic. At one level he is the nationalist arguing against colonial duplicity. But in the submerged archeology of the modern industrial state, the Pandit outclasses Holland as the technocrat.

In fact the Commission's Report itself is a text disfigured by

context. Historians have cited it to emphasize the constraints on Swadeshi industry or the duplicity of colonialism. The relation of the colonizer to the colonized is no doubt a fundamental aspect of the Report. But its rhetoric obscures the more complex character of the investigation, submerging a third level of analysis. Here colonizer and colonized combine to unravel the logic of industry. The comparative anthropology that emerges transcends the methodology of invidious comparison. It is no longer a case of Britain and India. Rather than a policy based on a history by subtraction, we observe a more structured analysis in terms of two sets of relations, of Britain lagging behind Germany, as India lagged behind Japan. Britain is no longer the relevant model of industry, but it is Japan as the Asian Germany that becomes the focus of analysis. We shall now proceed to unravel the triptych-like character of the Report through an analysis of Malaviya's note.

For Malaviya the methodology of the Commission's problem required a search for epochs where one industrial country lagged behind the other, and to examine the mechanism of acceleration. It is in this context that Japan becomes crucial to the analysis for it mediates the movement to the third sector of the triptych.

The evidence cited before the Commission revealed that the history of many a Swadeshi effort was inspired by Japanese achievements in ceramics, glass and steel. Underlying the odyssey of many an Indian visit abroad was the inspiration of the *ryugusei*, the foreign-going student who provided a creative push to Japanese industry. But Japan was not merely a cornucopia of procedures for successful industrialism, it was a challenge to the very ontology of western industrialism. One of the first acts of the Industrial Commission was to dispatch the economist C. J. Hamilton to investigate how 'Japan had developed a structure of industrial and commercial enterprise from a past which knew nothing of Western economic conditions'. Malaviya cites Hamilton's impressions as archetypically British. Hamilton observed that 'The Asiatics had long been considered intensely conservative, unprogressive, needing the help and guidance of Western nations and even with their assistance being with difficulty persuaded to adopt modern aims and methods, associated with economic progress.' (ICOM. Report, p. 294.)

In analysing the achievements of the Asian Germany, Malaviya

moves across to the last portion of the triptych. The argument here is no longer whether industry is endemic to occidental culture. By contrasting British industry and the Japanese achievement, Malaviya shows the irrelevance of such a question. Both nations are encompassed in the logic of import substitution industrialization. At the first level, Swadeshism argued for the displacement of foreign goods and workers by their Indian variants. The Swadeshism of the political movement becomes translated into the factory language of import substitution, which is culture blind as also to nationality. In advocating the importance of industrialism, Malaviya's argument encompasses the dialogue of nationalism and colonialism. We shall now proceed to unravel his argument regarding the logic of industry.

To the members of the Commission thinking about industry meant thinking about the organizations that go into the making of an industrial society. Implicit in the Commission's argument is a belief that modern technology as discourse requires a form to establish and maintain a network of relationships, that is, the production and reproduction of technology required the formal organization. The concept of the formal organization anchors in a deep and fundamental sense the Commission's discourse on industrialism. Basic to the argument is a distinction between two modes of industrialism embodied in their paradigmatic organizational forms, between the factory as a mode of coercion and the school as a medium of socialization.

In his note, Malaviya asserts that the factory as a mode of domination was a part of the de-industrialization process. Citing Romesh Dutt, Malaviya observes that when British weavers felt threatened by the silk weavers of Bengal, the East India Company advised that 'the silk weavers should be forced to work in the Company's factories and prohibited from working in their own homes.' (ICOM, Report, p. 297.) India, he argued, was to rejoin the industrialization process when it was largely accepted as axiomatic, and what was required now was an attempt to understand models of diffusion. Industry had been transformed from domination to discipline and had to be sustained. It is in this context that the school rather than the factory becomes the paradigmatic organizational entity.

In his reading of industrialism in the west, Malaviya discerns a

disjunction between two phases mediated by the great industrial exhibitions held in the eighteen fifties. The exhibitions were competitive trials of intelligence and skill between industrial nations. These surrogate wars, Malaviya pointed out, destroyed the cultural arrogance of industrial Britain, the myth that its command of coal and industrial skill rendered it superior in intelligence to the 'unironed, uncoaled and unengineered nations of the world.' (ICOM. Report, p. 323.) This unshakeable belief in the *laissez faire* triumph of its hereditary individual genius yielded to the concept of the school as the great leveller.

Citing the Commissions of inquiry that investigated the debacle, Malaviya observed that at the first exhibition in London in 1851, the French and the Germans realized their inferiority in industry to England. In response, they established a network of schools in every major town and centre of industry to create an industrial cadre extending from professionals to workmen. By the fourth industrial exhibition in Paris in 1857, the Commission realized that England was beaten in the 'battle for intelligence'. The Commission of inquiry stated that 'the English workman is gradually losing the race, through the superior intelligence which the foreign governments are carefully developing in their artisans. The education of Germany is the result of national organization which compels every peasant to send his children to school, and afterwards affords the opportunity of acquiring such technical skill as may be useful in the department of industry to which they are destined.' (ICOM, Report, p. 324.)

Implicit in the structure of the above text are three arguments which Malaviya elicits and elaborates. First, modern technology necessitates as a discipline a new linking of knowledge and power. It is the logic of this technology which eventually reconstitutes in a new fashion the state and the school. Both exist in order to ensure an economy in the reproduction of industrial norms. The intersection of knowledge and power is further embodied in the isomorphy between the pedagogic state and the compulsory school. The link between knowledge and power is also revealed in the special status given to the notion of intelligence. It is no longer regarded as hereditary but as an input to be fed in by the agency of the state. Intelligence becomes industrialized, standardized and productivity-linked in the new notion of personnel. It is the state which assumes responsibility for it through the school. This is

captured in Malaviya's cross-examination of Sir Alexander McRobert, Manager of the Cawnpore Woollen Mills.

Malaviya: Do you think that without any education, i.e. by nature the English workman is more intelligent than an Indian of corresponding status?

McRobert: As a general rule they are.

Malaviya: Do you remember Macaulay's description of the difference education brought about in the intelligence of the Scotsman?

McRobert: I am not strong on Macaulay.

Malaviya: I will help you to remember it, Sir Alexander. In a speech delivered in the House of Commons in 1847 Macaulay said hundred and fifty years ago the name of the Scotsman was uttered with contempt. But that some time after the parish schools had been established all over Scotland, an improvement such as the world had never seen took place in the moral and scientific character of the people and wherever the Scotsman went he rose to the top as surely as oil rises to the top of the water. Macaulay ascribed it to the education which had been made compulsory. Do you think that the intelligence of the Scotsman had been improved by education?

McRobert: No doubt in the days when they were cattle stealers they were not as intelligent in a civilized way as they became after the parish school was introduced.

Malaviya: In England education is compulsory for every boy and girl?

McRobert: It is believed to be, but I understand that there are ways of evading it just as vaccination is evaded. (ICOM. Minutes, Vol. 6, p. 280.)

In their evidence before the Commission and through persistent cross-examination, the advocates of Swadeshi sought to reveal the irrelevance of Britain for any scheme of industrial resurgence. One would have to emphasize that they did not invoke a theory of colonial duplicity. They realized that the idea of a formal applied science was new and that Oxford and Cambridge had 'not got over the feeling that humanistic studies should predominate in the Universities.' (ICOM. Minutes, Vol. 3, p. 150.) The attorney B. N. Basu testified before the Commission that the inadequacies of colonial education were a reflection of the prevalent theories of education in Britain. Basu remarked that

the ideals of ancient scholasticism are more or less the ideals of present-day English educationists and they still dominate the systems prevailing at Oxford and Cambridge and these have been transplanted to India where owing to the speculative genius of the people, it has found

congenial soil. Where practical men are wanted we have been given a race of pandits with this difference, that instead of studying the ancient literature of their own country, which might be of some use, they have learnt with considerable assiduity numerous facts like the conjugation and declension of Anglo-Saxon verbs. (ICOM, Minutes, Vol. 2, p. 142.)

Commenting on science, Basu referred to places 'where experiments were performed in chalk by a gentleman who was first or second wrangler of his time'. (ICOM. Minutes, Vol. 2, p. 150.)

It was the acerbic Holland who grasped the nature of the critique when he asked 'Do you think it is likely that the classical education which has been forced into the practical minded English boy has done him some good, and that possibly, on the other hand, the literary and philosophical education which our Oxford educationists have imparted to your people who are as you say endowed with a speculative genius, has resulted in their running into literary grooves in life? . . . You think we ought to have introduced for instance, instead of, or in addition to Chaucer and John Stuart Mill, the forge and the lathe'. (ICOM. Minutes, Vol. 2, pp. 147-8.)

Basu and Malaviya believed that England was incapable of providing such a model. This is revealed in the discussion between Hornell, Director of Public Instruction, Bengal, and Malaviya. Hornell admitted that in England 'the tendency of selective education is to sacrifice industry and agriculture for the professions. I have before me some notes from the Board of Education and from that I find that from London public elementary schools, the best boys go with scholarships to the secondary schools, the next best go to the central schools while the technical students are recruited from the residue. The tendency cannot be tolerated indefinitely'. (ICOM. Minutes, Vol. 2, p. 240.)

Malaviya in his cross-examination asks Hornell, 'Is it a fact that England had been much more backward in the matter of technical instruction than Germany?'

Hornell: Very much so. I do not think people out here realized that.
Malaviya: And it is not much good asking us to look for a model to England for providing systematic instruction for our youth (ICOM. Minutes. Vol. 2. p. 242).

Malaviya and Basu believed that the British ideas on education revealed their irrelevance as a model for an modern industrial

society based on applied science. Malaviya felt it was Germany and Japan as the Asian Germany that could provide the relevant solutions.

The massification of intelligence under the agency of the state that Malaviya dreamed of is captured in his description of Japanese efforts. 'The leap at education which the whole nation had made under the compulsory system is shown by the fact that while the primary school system was only formulated in 1872, by 1873 the number of schools had already reached 28%, by 1883, 51%, by 1893, 59% and in 1904, 93% of the children of a school going age.' (ICOM. Report. p. 326.) Malaviya concluded that some system of technical education was absolutely necessary. 'Other nations have already sixty years start on us, and have produced several generations of educated workmen. Even if we begin tomorrow, the technical education of all the youths of twelve years of age, who have received sound elementary education, it will take seven years before they commence the practical business of life, and they will form but an insignificant minority. It will take fifteen years before those children who have not yet begun to receive elementary education will have passed from the age of seven to twenty-one, and represent a completely trained generation, and even then they will find less than half their comrades educated. In the race of nations therefore we shall find it hard to overtake the years we have lost.' (ICOM. Report, p. 327.)

The notion of compulsion is a repeated theme throughout and is eventually worked out by differentiating the school from three other formal organizations, the prison, the mission and the army. The last enters more as a metaphor of discipline than as concrete ethnography.

The evidence before the Commission reveals that both the jail and the Mission were prominent centres of industrial activity and even constituted an innovation loop of their own. F. O. Maxwell, head of the Salvation Army, testified that the effectiveness of the various flyshuttle looms designed by his organisation were tested in various prisons and added that Inspector Generals and Jail Superintendents had spoken well of the machines. (ICOM. Minutes, Vol. 4, pp. 52-3). The chemist, F. M. Marsden, observed that it was only in the jails and the Missions of Madras that one found modern dyeing houses. Subramaniya Iyer of the Department of Industries, Madras, claimed that 'the Central Jail

at Vellore had helped serve the carpet industry' and held that 'but for certain jails in India the carpet industry might have been in much worse condition.' (ICOM. Minutes, Vol. 3. p. 179.) The Inspector-general of Prisons, Punjab, attested to this fact in his own province and provided the rationale for the jail as an industrial unit. Mr Ward saw the jail as a department of the government catering to in-house consumption, 'an action which is fully recognized by responsible authorities as the correct and proper one to take.' (ICOM. Minutes, Vol. 5. pp. 55-6.) The Swadeshi industrialist, Rai Sahib Panna Lal, argued that the jail was performing a patriotic service and advised that convicts must be used with greater advantage in making glass, glazed pottery and enamelling. These industries, he argued, 'came within the definition of hard labour and should replace hand-grinding corn and other drudgeries of an unrelieving type' (ICOM. Minutes, Vol. 5. p. 156). But private industry and the chambers of commerce objected especially to the use of power machinery in jails. The Commission upheld the objection, deemed the use of power machinery in jails as undesirable, and particularly disapproved of the tendency of jails to undersell private industry. The Commission stated that 'jail industries were not rehabilitative', observing that, 'it is almost unknown to find a man who has learnt such an industry try to practice it on return to liberty.' (ICOM. Report, p. 168.)

If the jail was rejected because it threatened to undersell industry, the mission-based industrial schools were not considered as proper models of diffusion because they worked parallel to it. The missions of the Salvation Army and those in Ahmednagar made important modifications in the flyshuttle loom, but lacked the ability to penetrate the market. Apart from the technology of the flyshuttle loom, the other innovation of the missions was the industrial school. The first schools were established after the great famines of 1877-8 by Canon Margolis, to cater to orphans and new strata of Christian converts who could not be absorbed into the cottage industries. These new schools sought to provide instruction in such trades as carpentry and weaving. As an organizational experiment they were successful. Those who had been trained as carpenters and blacksmiths found work in railway workshops, and the weavers and tailors supplied the needs of the Anglo-Indian community. (ICOM. Report, p. 110.) The Commission however

observed that both the mission and that other great model of industrial diffusion, the railway workshop, were particularistic entities. (ICOM. Report, p. 119.) The predominant recruitment for the latter was the Anglo-Indian community. What it sought to devise was a model of organization for diffusing industrialism to society at large.

At least one witness seriously thought of harnessing caste groups to serve as anchors for industrial diffusion. Hornell examined the dilemma of these artisan schools. They were unable to recruit craftsmen without the incentive of fat scholarships. 'No scholarship can compensate the boy or his parent for the loss of wages. . . . When compulsion is exercised as in the German continuation schools it may be successful.' (ICOM. Minutes, Vol. 2, p. 231.) Hornell wondered if some other system could facilitate the process of recruitment. He considered trade unions, but realized that India had none and noted that in England trade unions had always opposed instruction in artisan or graduate schools for fear of over recruitment. Hornell then considered whether caste groups could serve as functional equivalents and realized that an opportunity had been lost. 'Had caste been adopted as an educational unit in the first instance the result might have been different. It is in many ways a valuable social organization of which use might have been made. A democratic outlook in sociology has emphasized its worst features.' (ICOM. Minutes, Vol. 2, p. 230.) However, Hornell adds quickly that the institution was un-British and unnatural and that 'there never was a possibility of a constructive attitude toward it.' (ICOM. Minutes, vol. 2, p. 230.)

The other major institution discussed is the army, which enters more as a metaphor of discipline in the report. The idea of the workforce as an industrial army is implicit. The engineer F. A. Cox testified that while Indian workmen were quick to learn and had undoubted skill, they could not be relied on to maintain the standard of work without constant supervision. As an antidote he insists that the same degree of efficiency that has been instilled in the Indian soldier by strict discipline and the insistence of a high standard by British officers, can also be effected in the Indian workmen.' (ICOM. Minutes, Vol. 3, p. 353.) Malaviya is also prey to this metaphor when he quotes John Perrin's statement that 'a manufacturing country that depends on a few good

managers and an army of unintelligent slaves will fall as the Roman Empire fell' (ICOM. Minutes. Vol. 2, p. 248). It is eventually a British engineer who objects to the language of the discourse when he retorts to Holland: 'There is one type of remark in all these questions that jars on me, "you put him through", . . . "you send him here", . . . "you push him there," and so on. This is absolutely opposed to my system of training. We provided the facilities and the young men came to us, did the work, went out in the world, found a post and did things.' (ICOM. Minutes, Vol. 2. p. 369.)

The metaphor of the army underlies the notion of discipline incorporated in the idea of personnel. Even managers are treated in terms of an officer élite, an *élite-de-corps*. This is elaborated in the discussion between Chatterton and Heaton, the Principal of the engineering college at Sibpur. The latter complained that the Bengali was a reluctant engineer, whose method of learning was best expressed by the Bengali-English word 'by heart.' (ICOM. Minutes, Vol. 2, p. 249.) Heaton elaborated upon the problem of the Sibpur engineering college by contrasting it with the College of Engineering at Roorkee.

The Sibpur college had a three-tiered structure, each tier with its own career trajectory. The college was responsible for the training of officers for the various departments of civil engineering. It also provided for the training of supervisors and, for a short time, affiliated various technical schools, catering to carpenters, blacksmiths and tinsmiths. The Principal observed that the presence of heterogeneous groups at Sibpur 'would make gentlemen who are capitalists . . . chary of sending their sons to the college.' (ICOM. Minutes, Vol. 3, p. 262.) He also confessed that he could not 'give them the kind of accommodation they are accustomed to at home' and added that 'after my students leave and mix with deputy magistrates and other people they do not shine'. Heaton contrasted the situation with the more élitist college at Roorkee, 'where the students live entirely separate lives . . . were expected to live in a good style, to dress for dinner. My students have a joint mess with sub-overseers and overseers.' He also observed that every person who graduated from Roorkee was guaranteed a job at the level of an assistant engineer, 'While only one of my thirteen students was assured a guaranteed post.' (ICOM. Minutes, Vol. 3, p. 262.)

Alfred Chatterton observed that the training at Sibpur 'was not exactly suited . . . to produce a first class subordinate' (ICOM. Minutes, vol. 2, p. 262.) Sibpur had failed to attract students from the higher classes. Chatterton believed that the problem lay in the very structure of the University, which, with its emphasis on law and the humanities, had 'too powerful a hold in Bengal'. He suggested as an alternative the establishment of an autonomous technological institute modelled on the Osborne Naval College in England. On that basis he proposed a series of clear cut reforms. They were first 'cutting off the lower classes, those aspiring to be overseers and sub-overseers'. He recommended that recruitment should be made at the early age of fourteen and students then separated altogether from the University. Their curricula would include, apart from technical courses, a fairly liberal education to enable them to hold their own against government officers. (ICOM. Minutes, Vol. 2, p. 261.) They were also to be provided with an assurance of employment up to the executive engineers grade. To realize their vision, Chatterton and Heaton suggested the establishment of an imperial college of engineering, one great technological university embracing all branches of engineering. Heaton realized that such a proposal might not be within the limits of practical politics and suggested as a compromise the federation of the four existing colleges of engineering. The first two years of education would be uniform, and following that, each student would proceed to the college that specialized in his own branch of engineering.

One last issue remained to be solved. It was whether the technical schools were to be located under the department of education or the new department of industry. The participants realized that like any bureaucratic move it touched deeper questions. Implicit in such a classification was a distinction between mental and manual work and its cultural connotations. Classifications also determined the flow of resources, and the witnesses realized that such things determined life chances even in the rudimentary state coming into being.

The headmaster of the Andhra Jathey Kalashala, Hanumantha Rao, stated before the Commission that 'the question of the relation of technical education to the industrial enterprise is one of the most obscure passages of Indian public policy and must definitely be solved before general popular effort can be intel-

ligerly co-ordinated with national progress,' (ICOM. Minutes, Vol. 3, p. 80.) The debate took the following shape. On the one side were advocates of apprenticeship like Doraji Tata. Tata suggested that technical schools were a little too theoretical and much better work could be done by the factories themselves in the training of their own men. Tata cited as an example the success of his own cotton mills at Nagpur, which had done away with imported skilled labour, right upto the post of the manager. (ICOM. Minutes, Vol. 2, p. 244.) Hornell, in reply to this, stated that there was a real danger of technical schools being divorced from the work done in the workshops but added that 'the danger of the workers being trained only in the factories is that the system is apt to overlook the fact that the worker is not only a worker but that he is also a man and requires something more than technical training.' (ICOM. Minutes, Vol. 2, p. 244.) Hanumantha Rao elaborated on this point when he stated that manual work was devalued in the wider culture. The location of the technical schools under the department of industry would only serve to reinforce the gulf. Rao suggested that technical training had to be held up as a cultural ideal, visualized as a popular movement. It is in this context that he advocated the establishment of engineering schools under the department of education, 'for otherwise the Indian youth would instinctively turn away from training which holds out not the ideal of culture, but of purely professional training.' (ICOM. Minutes, Vol. 3, p. 80.) The spirit of this idea is also captured in an observation by Basu, who remarked that when Madhusudan Dutta was induced to perform an operation on a dead body, guns were fired from Fort William. 'In the course of time we got a fine class of Indian physicians and surgeons. So I do not see why if we fire a gun when the first Brahmin begins to make a shoe, we should not get in thirty years quite as satisfactory results.' (ICOM. Minutes, Vol. 2, p. 149.)

The Commission realized that the educational system was embedded in a structure of expectations. The 'P.W.D. State' had created a revenue service educated in the law and the humanities. The passport to jobs was a university degree. It was this bias that Spring attacked when he stated that government recruitments 'were habitually and systematically made from the literary classes' and that 'one of the first steps that the government should take was to emphasise that training in engineering was not a disqualification

for the revenue service, that a man who had been taught the principles of scientific survey was as competent a *tehsildar* as one with a history or law degree.' (ICOM. Minutes, Vol. 3, p. 76.)

Hanumantha Rao, the headmaster, went further and proposed a more drastic solution. He stated before the Commission that 'the whole scheme of education should be recast. The educational ideal must be kept entirely separate from the "service ideal". The educational ideal must exist for itself. Service must be kept entirely apart. Government servants must be recruited by special examinations if they care to have them. If the service ideal was kept apart, education would exist for itself and help develop the culture of the people. It seems to me if this change was made, there would be numbers flowing into the technical schools who would qualify themselves for the practical industries of the present age.' (ICOM. Minutes, Vol. 3, p. 85.) This point of separating the examination and educational system was also raised by Hornell and Malaviya but rejected as unfeasible.

The testimony quoted thus far is from the westernized élite. The manual workers in the traditional industries had a different perspective on the same question. Daivasikhamani Achari, Secretary of the Visvakarma Mahajan Conference Committee, stated that while the artisans were 'the industrial backbone of the country, they were not going to be the beneficiaries of the new policy regarding technical schools'. Achari observed that most manual workers were not educated and, lacking the exclusive literary training, were ineligible for technical scholarships, which required several years of formal education. Citing the 1911 Census Report on 'the complete dissociation of the intellectual class in the country from its industries', Achari remarks that 'the mistake lay in the very first steps taken, viz., in the selection of students to go to foreign countries for training, from communities other than industrial or artisan classes who possess the initial aptitude for manual labour, which a university graduate of any other class despised as a derogation of his caste dignity or literary merit.' (ICOM. Minutes, Vol. 3, p. 326.)

The Commission advised that the technical schools be gradually placed under the department of education. The report also made provision for the more general education of the artisan classes.

The eventual roster of organizations that the pedagogic state was to establish included the joint stock enterprise, the factory,

the technical school, the co-operative, the technological university and the industrial museum. It is the state, through the civil society of formal organizations, that was to usher the transition from agriculture to industry. Crucial to this process was the establishment of the co-operative as the formal entity which, functioning as an intermediate organization, was to facilitate the transition to large-scale economic enterprise. The Registrar of Co-operative Societies explained that

the part which the co-operative societies are likely to play in the industrial development of the country will be subordinate and auxiliary to the introduction of large-scale industries. The object of the industrial co-operative societies might be to familiarize the poorer and middle classes with the advantages of industrial combination and not to introduce industrial combination itself on a large scale for the development of the country as a whole. The special skill for management, the special scientific knowledge, the large capital that will be required for large industries cannot be made available except by Government departments and joint stock companies. . . . With large industries as an example before them, small industries will naturally come into being through co-operative societies and these may be gradually enlarged. (ICOM. Minutes, Vol. 3, p. 137.)

The notion of the state as an industrial and organizational innovator was thus no longer that of the residual one of the government of the 'P.W.D. era'. It was Francis Spring who once again captured the surprise at this wider ambit of innovation in the innuendoes of the following statement: When it was suggested that the government stores department should contract with local firms for its supplies, Spring remarked, 'Government custom is big business now, simply because of the accident we are not merely a government, but a maker of things. We do not merely govern the country, but also undertake what in more advanced countries would be done municipally and privately. But are we talking of paper and pencils now, or of bigger things?' (ICOM. Minutes, Vol. 3, p. 69.)

In the next section we shall examine the Commission's efforts to understand the nature of technology in relation to organization.

IV

W. Hornell, the Director of Public Instruction in Bengal,

remarked that the Bucherian model of industrial and Commercial evolution appeared inadequate for India. Bucher visualized the evolution of industry as a series of unilineal stages, beginning with house-work and wage-work, evolving into price-work which postulated the existence of a small town, to commission-work which assumes a cluster of towns, and eventually the factory system which assumes national trade. Hornell observed that it was difficult to place India within this sequential model of industrial evolution. He found in Bengal a strange admixture of stages. 'Housework is rare, but still exists, a good deal of cloth is woven in the house for domestic purposes. The goldsmith is an instance of wage-work. The brass worker is an instance of price-work. The potter is a commission-worker. In jute, cotton, steel we find the factory on a large scale: in soap, printing and jewellery, we see the small-scale factory.' (ICOM. Minutes, vol. 2, p. 227.) Hornell added that the gradual development from one stage to another was not possible. 'A local artisan does not swell into a shop, thence to a factory. He is apt to be faced suddenly by world products and thus he usually disappears unless he develops into a factory supplying the world.' (ICOM. Minutes, Vol. 2, p. 228.) Instead of a sequential development of stages the Commission was confronted with a synchronic juxtaposition of different activities. Implicit in the Commission's cross examination is a search for a classification of industry in order to specify the role of the state to each sector.

The Commission decided that there were two industrial systems working side by side. The first described those industries which were carried on in the homes of workers and were designated cottage industries. The scale of operations was small, and there was but little organization. As a rule they catered to local needs. (ICOM. Report, p. 160.) The second category, the Commission recognized, were the organized industries ranging across the spectrum 'from simple rural factories carrying out a single operative process to the big textile mills and engineering works, employing thousands of hands, possessing a complete organization for both manufacture and trade.' This category was again subdivided into the 'small organized and the large organized industries.' The industries involved in the former were mainly provincial in character and included tanneries, sugar factories, cement works, glass factories and wood distillation plants. In the second class were industries with national and international

ramifications involving heavy capital expenditure. These were the 'heavy chemical works, iron and steel works, ordinance factories etc.' (ICOM. Report, p. 160.) The Commission attempted to understand each of them in terms of the nature of their technology, the personnel required and the organizational and entrepreneurial questions each entailed. We shall explore in particular the problems of technology.

As far as the British attempts to understand traditional and small-scale technology were concerned, the efforts of two officers, Alfred Chatterton and Fredrick Nicholson, were discussed in detail in the Commission's Reports. Nicholson presented a fascinating paper on industrialization in India based on his own experience in the country and on his visits to Japan and Germany. His reports were described by Malaviya as 'the most valuable of all the notes presented to the Commission.' (ICOM. Minutes, Vol. 3, p. 425.) Chatterton's experiences are described in a condensed Memorandum on the Department of Industries. They were described in greater detail in his *Industrial Evolution in India*. (Chatterton, 1912.)

Alfred Chatterton was not a Cooper's Hill engineer. The prize engineering jobs in the Imperial Service were for a long time the sole preserve of graduates from this college established solely to serve the needs of the empire. A graduate of Finsbury Technical College and The City and Guilds' College, London, Chatterton joined the Madras Educational Service as Professor at the College of Engineering. In December 1897 he was appointed Superintendent of the School of Arts. In 1906 Chatterton was made head of the department of industries. After the department was disbanded, his services were loaned to the Mysore durbar. He had one of the most fascinating and complex careers in technological innovation in colonial India. An outstanding ethno-technologist, he was in fact one of the first great advocates of intermediate technology. The spectrum of Chatterton's efforts ranged from experiments in well irrigation and pumping, to weaving, chrome-tanning, and the establishment of Madras Aluminum Factory. Chatterton was one of few officers who admired the history of technological effort in India. He explicitly cited the Mughal canals and Dravidian tanks as outstanding efforts. But he went beyond this historical invocation to establish the rationality and efficiency of traditional technology.

In 1899 Chatterton and Benson (of the department of agriculture) began a study of the efficiency of traditional technologies dealing with well irrigation. Based on their studies of practices in south India, the two engineers concluded that 'the method of applying animal or human power to lifting water is, if not perfect, exceedingly hard to improve on. The *peccotah* is a very efficient waterlift for heights ranging between ten to twenty feet and though at first sight it might seem that to employ one man solely to tilt the bucket and guide the lifting rod is a waste of energy; yet it is not really so, as by shifting around from time to time, each man gets the needed rest and work goes on, without exhausting the two men for a longer time than would otherwise be the case.' He also noted that various experiments had attempted to improve upon these methods and had failed. 'The indigenous methods are the result of long experience and are possibly an example of the law of the survival of the fittest—that is, of methods of drawing which are most suited to the environment and the resources of the ryots.' (Chatterton, 1912, p. 317.) The experiments led Chatterton and Benson to conclude that they were not likely to effect any marked improvement on the indigenous methods of lifting water. Chatterton noted that it is only when animal or human power could be replaced more efficiently by machine power and where economies of scale could be effected that modern methods came into play.

Chatterton realized that it was this transition from traditional to modern technologies that was problematic. He had a great respect for the artisans he had worked with and contended that 'there will be no opposition to the introduction of improved tools or improved methods of working if it can be clearly shown that they are real improvements. The reputation that Indians are averse to all change and are obstinately wedded to the antiquated ways of their forefathers is not justly deserved. They are conservative but they know their own business fairly well and many of the so-called improvements they rejected were really unsuitable innovations.' (Chatterton, 1912, p. 22.) He referred in particular to the various 'worthless patents taken out for domestic handlooms' in India. He also cited as examples of successful adoption, the Singer sewing machine, the use of the fly-shuttle loom over the native handloom and of cast-iron mills instead of wooden mills in the sugar cane industry. Chatterton observed that modern technology tended to replace the man by the machine, the individual by the factory, and

the isolated factory by the organized trust. The British had tried to introduce such a system in India but it had not yet taken root. He argued that there were two alternatives before the engineer: either to accept the system as inevitable or to apply the resources of science and engineering in search for an alternative. Chatterton held that the advances of science made it possible to organize small-scale technology efficiently. He stated that 'the problem to be solved is the difficulty of finding a happy mean between the individual working for himself and the great capitalistic organizations employing hundreds of operatives in lives of monotonous drudgery.' (Chatterton, 1912, p. 28.)

Chatterton wondered if it was necessary for India to follow the same lines as the west and believed that the country offered fascinating possibilities for an experiment. 'It had not yet accepted the factory system and not was it likely to do so willingly.' Simultaneously, he admitted that India's political position made it vulnerable to influences from Britain and the rest of the world. 'Yet there was no reason why it should not strive to move forward to a goal more in harmony with its traditions rather than that of Western civilization.' (Chatterton, 1912, p. 23.) We shall now proceed to describe his experiments.

Realizing that the power loom had invaded almost every branch of weaving, Chatterton noted that it had been subject to constant improvement by ingenious 'mecanicians'. The handloom however had had not received equal attention in recent times and had been swamped by romantic myths. He felt that what was required was a scientific study of the areas in which the handloom still functioned competitively, in order to improve its range and efficiency. In 1900 Chatterton realized that fly shuttle looms were an improvement over the native handlooms after he set half a dozen fly shuttle looms at the School of Arts. In 1905 he rented a bungalow in the weaver town of Salem to begin more systematic experiments to ascertain whether it was possible to improve the condition of handweavers in south India. His innovations concentrated on three fronts. He substituted the native handloom with improved handlooms to increase production. At the same time, he tried to assure that the essential characteristics of hand-woven cloth were maintained. He also attempted to economize on the preparatory processes which the yarn undergoes before it is placed in the loom and tried to introduce a factory system so that the weavers worked

under the supervision of men with better commercial and manufacturing experience. (ICOM. Appendix J, p. 411.)

Chatterton held that it was only by working under a factory system that clear results could be obtained concerning the efficiency of various looms. He tried to attract workers with good wages and the promise of continuous employment, but was unsuccessful. The weavers preferred working in their homes assisted by women and children and evinced a dislike for the discipline of the factory. Chatterton had to be content with the waifs and strays of the weaving community, but he was still able to prove the superior efficiency of the fly loom. However, the weavers were unwilling to accept it. Chatterton then modified his strategy. He introduced the idea of peripatetic weaving parties to demonstrate various improvements to the weaving community. Within ten years a census revealed that 6500 of the 15,500 looms were fitted with fly shuttle slays. (ICOM. Appendix J, p. 412.) Chatterton estimated that it increased the net income of the workers by Rs 4½ lakhs per annum. He admitted that his attempts were only partially successful and emphasized the need for further experiments.

One of Chatterton's more successful efforts was in the introduction of the chrome-tanning process. Prior to his experiments, leather in India was processed by vegetable matter and generally exported as raw produce. The Madras skins were in great demand till the introduction of chrome-tanning in Europe. At the time when Chatterton took up the process there was a general feeling that chrome-tanning necessitated the introduction of machinery on a large scale, and the methods of operating adapted to more advanced communities. Chatterton set out to disprove this view. The experiments were conducted on a small scale, the establishment consisting merely of a tanning master, a flesher and three coolies. Within a year sales of chrome leather amounted to Rs 4000. A bootshop was opened on Mount Road and twenty thousand pairs of sandals were sold in 1907-8. (ICOM. Appendix J, p. 407.) But private industry objected to the commercial role of the factory. It had also earlier objected to Chatterton's successful attempt to establish the Madras Aluminium Factory, which was the main supplier of aluminium vessels in India. The control of the aluminium factory passed into private hands and the chrome-tanning experiment was dismantled.

The success of the department of industries in establishing the Madras Aluminium Factory and in introducing the chrome tanning process raised important questions before the Commission. What exactly should be the role of the government in establishing 'pioneer factories'? What should be the degree of involvement of the state in technological innovation? One of the most cogent and influential answers was given by Fredrick Nicholson.

Nicholson was not content with a government that merely gave loans to nascent enterprises. He wanted it to assume the role of the risk taker, to establish and maintain pioneer industries and emphasized that these factories should not be handed over immediately to private enterprise once the initial feasibility of the enterprise was established.

He observed, 'It appears to me a mistake to suppose that government pioneer factories should necessarily be closed down or handed over to private enterprise as soon as they have made their proofs. Technical and commercial successes are not the only *raison d'être* of such factories. They are responsible for the training up of experts from managers to artisans, instructors and perhaps inspectors.' (ICOM. Minutes, Vol. 3, p. 390.)

Nicholson emphasized that the innovation process was a continuous one where the technologist was 'necessarily finding out new difficulties, new methods and new recipes'. Given this, the pioneer factory became a place for industrial research and development. Citing the example of his own work on canning and soap, Nicholson stated that the canning factory would lose its value as a place of instruction and experiment if he were to succumb to the offers made and sell it. Nicholson argued that the technology of canning though feasible for many years had not developed in India because 'there was no one to spread the knowledge of the secrets of canning. They had all to be ferreted out by the experimental work of the factory and if it were now handed over to a private firm, the experience gained would remain secret and development would again be arrested.' (ICOM, Minutes, Vol. 3, p. 390.) Nicholson concluded that the closing of a pioneer factory should be decided only after a detailed evaluation of the conditions local or individual to the industry. He suggested that 'in the more complicated industries such as those of applied chemistry any such relinquishment should be deferred far longer than in simple mechanical industries.' (ICOM. Minutes, Vol. 3, p. 390.)

Nicholson went on to suggest that the debate over pioneer factories should not be viewed merely in terms of the opposition between state and private enterprise. He argued that the state had to play the role of buffer between the great western trusts and the small enterprises. Citing the example of the soap industry, he noted that Lever Brothers had already obtained a foothold in Asia by establishing a factory in Japan. He emphasized that it was the state that must, through the pioneer factories, provide a place 'where the small folk can learn the soap "mystery" and give this presidency a large chance of successful competition with the great western trusts.' (ICOM, Minutes, Vol. 3, p. 390.) He emphasized the need for protection and, referring to the terms of the Commission, remarked, 'This part of Hamlet seems to have been left out'. He also suggested that the government stores department should place orders with these enterprises: 'Saddle soap and ordinary soap by the military department, plain and medicated soap by hospitals, schools and institutions.' (ICOM, Minutes, Vol. 3, p. 400.)

Nicholson was eager that the state play a role in the revival of cottage and small scale industries. He drew up a list of thirty-five industries with suggestions of how to revive them and made fascinating observations on clocks, toys, bicycles and umbrellas. Spearheading the activities of the pedagogic state was the industrial museum. Both Nicholson and Swadeshi industrialists like B. M. Das (National Tannery) and S. C. Deb (Calcutta Pottery) wanted to exploit the role of the market fair in the diffusion of technology. They sought a formal equivalent for it in the industrial museums in Germany and Japan. The museums consisted of two parts. They included an exhibition of products from abroad intended for local imitation, but juxtaposed with these were collections of samples from every category of local industry. Nicholson observes that they were singularly free from red tape; admission was free and visitors were allowed to touch, handle and measure any item they wished. The catalogue of the museum had detailed and accurate pictographic accounts of each stage of the operation. They were so comprehensive that they had acquired the status of technical monographs on the subject. One of the most remarkable sections dealt with the textile industry. Outstanding samples and designs were obtained from all parts of the world and stored in many hundreds of volumes. The weavers were allowed to inspect these samples and even cut off portions for

study and imitation. Supplementing all this was a splendid technical library. In addition, the Tokyo museum kept in active touch with consulates and museums abroad. To Nicholson and the Swadeshi industrialists such a museum was not a static, quiescent body, but an aggressive propagandist organization mediating between manufacturers and buyers both at home and abroad. The impact of this imaginative 'National Research and Development Corporation' was immediately visible in the revival and improvement of numerous industries in Germany and Nicholson proposed the establishment of a similar museum for India. (ICOM. Minutes, Vol. 3, p. 393.)

Supplementing the industrial museum would be agencies for standardization to assure quality control. The model was once again Japan, where the state in collaboration with the existing 599 guilds had gradually enforced standards of production 'which should shortly relieve Japanese goods of any *odium loci*.' (ICOM. Minutes, Vol. 3, p. 393.)

The Industrial Commission was greatly influenced by the arguments of officers like Chatterton and Nicholson. Yet the Commission was pragmatic enough to understand the power of private enterprise. It was due to the opposition of the chambers of commerce that Chatterton's chrome-tanning factory was prematurely disbanded and in this context the Commission made what it itself described as 'the greatest departure of the old *laissez faire*' (ICOM. Report, p. 159) by emphasizing the role of the state as innovator. It however felt the need to make a distinction between 'pioneering' and 'demonstration' in reference to state aid for industries.

The Commission defined 'pioneering' as 'the initiating by government of an industry on a small scale to ascertain and overcome initial difficulties.' (ICOM. Report, Vol. 3, p. 159.) The Commission emphasized that the government would establish a pioneer factory only when private initiative was not forthcoming. It also emphasized that the government would not close down the factory as soon as a private individual or person was willing to take over. (ICOM. Report, p. 359.) It added that such a decision would only be reached after a full review of the circumstances of the case and mentioned that the factory might be maintained long past the initial stages of development. It is in this context that it referred to 'demonstration factories'.

It was suggested by the Commission that a government factory which has passed through the pioneering stage could serve as the training ground for managers and workmen in that industry or as a site to introduce new improvements in a technology. As an example of the first it cited the glass factory where operatives could be trained. As an example of the second, it cited the case of a silk-reeling and throwing-house to demonstrate the advantages of modern methods of operation at the factory scale over the existing indigenous cottage methods. (ICOM. Report, p. 159.)

Such factories, the Commission added, 'would be regarded as equivalents of the demonstration farms in agriculture. These demonstration factories were to cater basically to cottage industries'. The Commission concluded that 'if the object with which each factory of this class is started is kept in mind, there can be no doubt that so long as it fulfils its primary function, it can prove useful and can in no sense be regarded as likely to interfere with the development of private enterprise.' (ICOM. Report, p. 360.)

The experiences of Chatterton and Nicholson no doubt played a crucial role in the shaping of the Commission's Report. But we must emphasize that while the Commission was influenced by the work of these technologists, it rejected the overall logic implicit in their arguments. Both Chatterton and Nicholson emphasized the importance of the craft traditions, and saw in them the possibilities of a different organization for technology. This wider vision of an 'intermediate' or modified craft technology received its most systematic articulation in the testimony of John Ashford, Superintendent of the central workshops division at Amritsar. All three engineers saw industry as a triadic relation between technology, organization and energy and believed that the new sources of energy would provide greater flexibility to technological organization. In fact, Nicholson was among the early advocates of solar energy, while Ashford anchored his vision on electricity. (ICOM. Minutes, Vol. 3, p. 411.)

John Ashford was a native of Birmingham, steeped in its craft traditions. He realized that the modern factory could not be eliminated altogether, but emphasized that a rereading of industrial history would reveal possibilities which could be more fully realized in India. Ashford focussed his analysis on Birmingham, which he dubbed 'Watt Country'. (ICOM. Minutes, Vol. 5, p. 314.) He observed that industry in this area did not begin with

the factory system but in a network of workshops, generally attached to the homes of the craftsmen. Even when the division of labour became more complex, and even after steam power was introduced, the 'craft tradition remained alive under the 'putting out' system. The craftsman still retained control of the work process, taking work as an 'outworker from the mastermen who were really the business organizers that made the system possible'. Out of these craft technological traditions arose the great innovations of Watt in metal forgings, Alfred Stanley's metal works and Starley's 'Spider Wheel' which culminated in the Rover Cycle Company. (ICOM. Minutes, Vol. 5, p. 314.) Ashford emphasized that these craft traditions were still a part of modern industry and that it was now the task of the state to help establish industrial villages composed of networks of these innovative craft workshops. In Ashford's description, each settlement catered to one industry or group of industries using either similar materials or similar methods. 'To particularize, the various workshops within one settlement would produce a variety of different articles each made with bone as its chief element, as for instance, bone buttons, shirt studs, fancy ornaments, tooth brushes, shaving brushes, combs, knives, handles, pen holders, paper knives and possibly also in the same settlement horn and celluloid could also be worked. The waste product from the working of bone could be boiled down into glue or be refined into isinglass, or again it could be converted into fertilizers.' (ICOM. Minutes, Vol. 5, p. 322.) Ashford proposed a series of such settlements centering around fibres, tin, sheet iron, fruits, wire and paper pulp.

Ashford emphasized the importance of organization as a central fact of these communities. The rules of the settlement were to be framed to foster industry and discourage sloth. Each settlement would consist of a series of small groups of buildings, each group to accommodate a family or a man and his journeyman. Electricity would be supplied from a central power station and to ensure aesthetic surroundings the entire settlement would be planned by a town-planning expert.

The settlement was to emulate the factory in its system of management, storekeeping, payment and sale of produce but was to differ radically in other respects. The village would lack

the confines of factory walls, or the imperious summons of the factory bell; there would be a measure of freedom for the man and his family. He

would not be separated from them while pursuing his labour and they would refer him assistance for their mutual benefit and his children would automatically learn the mystery of his trade in early youth. The man would commence his work when he liked, take his food when he pleased, and visit his friends when he wished; his only restraint being that he must produce a minimum of work. He would be relieved of the worries of finding a market for the goods he makes and the materials he needs could be purchased wholesale in the cheapest way, rather than in dribbles from the high-price retailer. He would be protected from the thralldom of the bania... (ICOM, Minutes, Vol. 5, p. 324.)

Ashford's model of the cottage workshops was the Swiss watch industry, which had grown in small cottage workshops, with the use of machinery driven by power from water wheels. Ashford saw the possibilities of such a system in the Punjab, where water power was running to waste. But his proposals were greeted with scepticism. Dorabji Tata wondered how this family workshop was going to compete against the large factory system and commented:

That is all very well in the beginning, but do you think you can develop large industries by such a system as they do, for instance in America? They turn out, for example, watches as cheap as five shillings, simply because every part is standardized and they make them by the million, and it is all turned out on a factory scale, every part being separately made and put together. (ICOM. Minutes, Vol. 5, p. 366.)

Ashford's plea that similar watches were being turned out in Switzerland on the cottage system was of no avail. The response of Tata to Ashford echoes Spring's comment on the Swadeshi movement that 'small hole-in-corner cement plants can never be expected to turn out good cement continuously.' (ICOM. Minutes, Vol. 3, p. 70.) The vision of Nicholson and Ashford was accepted only in a stunted version by the Industrial Commission. The industrial village remains in its rudimentary form as a co-operative, a transitional mode on the way to fuller industrialization.

In the next section we shall examine the Commission's conception of the role of science in an industrial society.

V

We began with the discussion on the location of scientific activity. The directors of the Great Surveys decided that as far as the

biological and geological sciences were concerned 'the more important part of the work should be done in India.' The arguments were both in terms of the requirements of systematic research and the demands of commercial utilization. The Director of the Geological Survey complained that references of samples sent to the Imperial Institute in London were unsuccessful, thanks both to the delay in and the quality of information supplied. But it was the Indians testifying before the Commission who pointed to the anomaly of using the Imperial Institute. G. A. Mahmadi, a scholar at the Institute of Science in Bangalore, observed that the main work done by the Imperial Institute was to analyse raw products in order to find a market for them. The only benefit that accrued was that India's raw products found a demand in England. 'But as far as Indian industries are concerned it was of no use. . . . What was even more peculiar was that Indian revenue was taxed to create this anomalous condition.' (ICOM. Minutes, Vol. 3, p. 558.)

The Commission accepted the arguments of the scientists and concluded that 'the study of raw materials required for industries can be undertaken effectively only by suitable scientists working on the spot.' (ICOM. Report, p. 102.) The Commission decided that geological, biological and chemical research in the form of the newly proposed chemical service would be located within the country. In order to be relevant to industry, all these sciences had to account for local variations and requirements. Almost unconsciously, and perhaps following the prevalent hierarchy of the sciences, industrial research in physics still remained removed from India. When the eminent engineer Francis Spring was asked, 'How is physics to be provided for? Ought we to provide anything in the country corresponding to the NPL?' he replied, 'as regards most physical science problems, we can get the work done in Europe as well as it can be done in India, but in the case of the biological sciences, especially economic biological science, the evidence so far tendered to the Commission shows that research work should be done in this country.' (ICOM. Minutes, Vol. 3, p. 65.)

Complementing the question of the location of scientific activity was the more controversial question of the recruitment of scientific personnel. The issue was whether the upper echelons of scientific research should be the sole preserve of British personnel. In this

context Madan Mohan Malaviya observed that the import of experts from England had not only increased the cost of these services to India but prevented Indians from being trained for work in them. 'We can never forget that so distinguished an Indian as P. C. Roy did not find admission into the Indian Educational Service. We know that though the GSI has been in existence for sixty-four years, yet upto 1913 only three Indians have been appointed to the superior service in it.' (ICOM. Report, p. 352.) Citing the testimony presented before the Royal Commission of Labour, Malaviya stated that of the 407 officers in the veterinary, forest, geological and railway services, only six were statutory natives of India. Malaviya was afraid that, despite repeated declarations to the contrary, the Imperial Service would remain the monopoly of Europeans, while Indians remained confined to the provincial services. But the Commission was less preoccupied with the problems of the recruitment of Indian personnel, and more with the new organizational changes required to enable these organizations to serve industry effectively.

The Commission observed that the science subjects having a direct bearing on industry and meriting special organization were geology, botany, zoology and chemistry. The movement from the plantocracy to the technocracy began with the attempt to transform the Surveys. The Commission realized that these organizations were outgrowths of the Asiatic Society, which was suffused with the spirit of a mercantile era, when scientific societies were modelled on the Garden Academies. Their goals were the map and the catalogue, culminating in Rennel's atlas and Roxborough's classification of plants. The Commission acknowledged the economic contribution of the Surveys to the cultivation of new drug-yielding plants and the knowledge of mineral resources. But it realized that these organizations lacked the resources and the personnel to cater to their new organizational responsibilities. Despite their imperial titles, the Great Surveys were skeletal organizations. For example, the Botanical Survey of India had a paid staff of one European and two Indian officers. Dr Annandale of the Zoological Survey testified that his organization had to find out all it could about the animals of India with a staff of four scientists. The directors emphasized the necessity of reasonably funded organizations with adequately paid scientists. Annandale remarked that some 'years ago I had an opportunity to call at

the Indian Office and interview one of the chief permanent officials. In the course of the conversation I remarked that one could not expect men to come to India unless they were decently paid. His reply was "Why don't you get Germans? They are cheap." In my opinion there is nothing more extravagant than a "cheap" scientist'. (ICOM. Minutes, Vol. 2, p. 661.)

The scientists also emphasized that the relation between the Surveys and industrial activity would be an informal and indirect one and insisted on the primacy of systematic research. Hayden of the GSI contended: 'the primary object is the completion of the Geological map of India.' (ICOM. Minutes, Vol. 2, p. 373.) He commented on the 'unwisdom' of employing a geological staff merely as an army of prospectors. But here again it was the Director of the Zoological Survey who was most explicit in warning against the *a priori* emphasis on applied science and the bureaucratic pathologies implicit in it. 'In the present state of scientific organization in India, I find it necessary for the protection of the officers of my Department to draw a line which I recognize as artificial, between pure science and applied science. With the officers responsible for the latter, the relations of the GSI have been defined as co-operation without subordination.' (ICOM. Minutes, Vol. 2, p. 660.) The duty of the Survey, he insisted, was systematic research. It was the responsibility of the entomological and fishery experts to apply zoological knowledge to practical problems. Annandale went on to elaborate the danger of confounding the two roles.

At present we are ignorant of many of the fundamental facts about food fishes in India. We know little about their history, their feeding habits or their enemies. The fishery experts whose training is in zoology are given no time to study such matters. Their duty is to supply results. They are therefore employed to can sardines or to arrange for the sale of fish in the market. If a product that tickles the palate of the administrator is produced at great cost, a technological triumph is claimed. . . . It seems as ridiculous to expect a fishery expert to be an expert fishmonger, as it would to expect me, who has written a paper on reptiles to charm snakes. (ICOM. Minutes, Vol. 2, p. 661.)

Thomas Henry Holland, the President of the Commission, realized that these leisurely suggestions would not do. He found the scientists in India largely isolated, 'each doing his own work in his own little laboratory. . . . They take a number of small

problems, work at them for a while and when they get results, they are unable to follow them in practice. They go on leave with no one to take up the work on the same lines and there is an enormous amount of valuable time frittered away in this fashion.' (ICOM. Minutes, Vol. 2, p. 524.) Holland cited an example of such waste—the organization of chemists in India. He found chemists scattered over the country in the Geological Survey, in the forest and agricultural departments, doing work that overlapped and publishing isolated reports inaccessible to the public. 'Each little chemist in his own province is independent, the amount of work he does is left to his own conscience' Holland emphasized that it could no longer be a question of conscience, but of pace-setting. He realized that if 'we are to tackle the problem of developing India in competition with the rest of the world, we have to move forward on a totally different scale'. The metaphor and the language of the army pervades his argument. 'There is no doubt that in the future our scientific men will have to be regarded as part of a defence problem.' Emphasizing the necessity of avoiding waste, he talks of the necessity of 'effective artillery preparation in the way of scientific research, . . . extending and organizing it so as to reduce the quantity of scattered fire.' (ICOM. Minutes, Vol. 2, p. 524.) Holland saw the challenges and opportunities before him, but what he sought to create in the new chemical service was a hybrid system. 'We do not want a form of organization that is characteristic of German *Kultur*, but we do want to go beyond the present British system of every man going his own way. We have in India a clear slate and fewer vested interests to break and we ought to be able to organize it in such a way as to steer between the two extremes . . . (ICOM. Minutes, Vol. 2, p. 527.)

The Industrial Commission was looking for a rational system of classification on which to devise a personnel policy for the new chemical service. It found two alternative models of scientific organization in India, each embodying a different system of classification. The vertical system of classification which took a single subject as its line of grouping was epitomized by the GSI. The horizontal system demanding the co-ordination of various sciences to a practical problem was concretely represented in the department of agriculture. Here it was the application of the various sciences—chemistry, entomology, botany—to agriculture,

which served as the principle of organization. The Commission then examined the arguments for both modes of classification. The case for agriculture was made by F. G. Sly, an ICS officer.

Agricultural research, Sly emphasized, required a thorough and continuous local investigation of each district tract. No central institution, however large its staff, could provide for such a continuous investigation of one locality. In such a system the value of an expert increased with the length of time spent in a province. Thus, any system of deputing experts for short periods could not be as fruitful as one in which an expert was kept for a substantial period, preferably that of his whole service, investigating the same conditions and thus acquiring a definitive knowledge of the agriculture of the tract. Sly emphasized the complex nature of agricultural research. 'It is not a problem that deals with botany alone, it is a problem on which experts work together; the expert agriculturist, the chemist and the botanist, are all bound together in the solution of every problem. You cannot depute the chemist in the agricultural department to do a particular piece of work and say that the work is finished. He must be on the spot, for the agriculturist wishes to refer to him, requires his assistance in the particular work he is doing.' (ICOM. Minutes, Vol. 2, p. 526.) Sly felt agriculture did not deal with problems as homogenous as those of geology. This was made even more complex by the fact that, apart from a scrupulous regard for local conditions of climate and soil, one had to be sensitive to established custom. The man must know the ryot as well as the soil. Sly argued that these were the principal difficulties in the way of placing the botanist and the chemist in watertight compartments.

To Thomas Holland, the choice was not merely between two modes of classification. He thought of agriculture and industry as two separate modes of social organization. The corollary to this view was the argument that the organization of science for industry would be different from the organization of science for agriculture. He thought of agriculture as a muddy system. He claimed that 'many of the industries we hope to take up will be less affected this way by soil and climate and they will be more universal in their application'. Holland scrupulously dissected the 'agricultural point of view' because he felt 'that the weakest part of the organization scheme will be where it touches agriculture.' (ICOM. Minutes, Vol. 2, p. 527.) He felt that the organization of the department of

agriculture did not conform either to current trends in administration or science.

Holland saw the members of the agricultural department as a heterogeneous group of people. 'At the Pusa Research Institute the scientific officers include mycologists, economic botanists, bacteriologists, and chemists. In each of the provinces one finds in addition to one or two recognized agriculturists, representatives of some one or more of these accessory variety of scientific officers.' (ICOM. Report, p. 88.) Each of these specialists worked in an isolated manner. 'The chemist, the entomologist and the botanist of each agricultural department is a law unto himself, and without the stimulating influence of other men of the same specific caste' (ICOM. Report, p. 89). Compounding this problem was the absence of centralized publication. 'These specialists find it necessary to publish their results in extra-departmental journals.' The plant pathologist at Pusa, for example, found that his most suitable journal was one published in Berlin and his scientific interests thus 'tend to be closely linked with German vegetable pathologists than with his colleagues in the agricultural department of India.' (ICOM. Report, p. 89.) He observed that the heterogeneity of specialists in service created problems in career planning. The accessory officers commenced at a higher initial pay and had better prospects than the officers of the Geological Survey in the first decade of service. 'But their official prospects are limited to a disappointing short and blind alley into which they enter at an age too young to consider the ultimate aspects of the question.' (ICOM. Report. pp. 88-9.)

The Commission found the military clarity it sought in Holland's old organization, the GSI, where the boundaries of the subject dove-tailed with the boundaries of the organization. Several advantages stemmed from this compact structure. First, there was the sheer clarity of goals and boundaries. 'Every one in India, whether an official or private person, knew exactly whether a problem does or does not come within the province of the Geological Survey'. Given the clarity of boundaries, 'no other official, local or central, could pose as an authority on mineral resources without trespassing on the functions of a recognized and established department.' (ICOM. Report, p. 88.) With the emphasis on clarity, followed a sense of identity which Holland enshrined into the axiom that no scientific man should be made

subject to another scientific man except of his own kind. The department's memoirs were regarded as the standard publication on India and enabled it to enjoy the benefit of a monopoly in making exchanges with institutions abroad. As a result, the GSI possessed one of the most satisfactory reference libraries of its kind. Holland felt that these circumstances added prestige to the department and fostered a sense of *esprit de corps*.

Holland realized that, while opting for a particular mode of classification, the Commission had also to decide whether the services were to be administered along imperial or local lines. His choice was for a centralized imperial system but he realized that he had to confront the fact that the officers of the imperial service would not be under the control of the local government. There was thus a possibility that local interests might be neglected, but Holland was convinced that an adequately manned service could easily cater to local demands.

The functions of the scientific service were to be advisory rather than executive. Consequently, the quality of scientific advice was more crucial than promptness of action, and technical efficiency more important than local knowledge. Science, Holland felt, was a specialized affair. A physical chemist could not substitute for an organic one and any attempt to do so was harmful. Holland believed that local governments were too small to provide such a variety of scientific specialists or even the equipment required for research work. Local governments could not offer the prospects necessary to attract top scientists. They were too isolated to provide the systems of peer group control that a centralized organization under a distinguished head could do. A central organization could provide all this and still retain flexibility. It was possible to organize an imperial science so that some officers were placed temporarily under the local government for special investigation of a local nature. When an officer in the provinces was found unsuitable in any post, he could be returned to the imperial reservoir and placed in a more suitable situation. (ICOM. Report, p. 91.)

The Commission proposed a new chemical service under the department of industries. It was to be headed by a chemist with a salary of Rs 3000 per month with the position and responsibility of a surveyor-general. He would advise the government on all chemical problems and also in matters relating to the promotion of

chemists and the suitability of articles to appear in monographs of the chemical service. Placed under him were three deputy chemists in charge of three main technical groups, physical chemistry, mineral and metallurgical chemistry, and agricultural chemistry. Regarding the matter of recruitment, the Commission advised: 'To the utmost extent possible junior appointments should be made from graduates of Indian universities, and the senior and experienced men who will be required to initiate and direct research should be obtained on special terms from England, when such are not available here.' (ICOM. Report, p. 93.) It ended with the sanguine hope that as science teaching grew and developed, 'the necessity for importing specialists will greatly diminish and ultimately the services will be filled by officers from this country.' (ICOM. Report, p. 93.)

The Indians before the Commission were skeptical about the idea of a chemical service. Malaviya and Puran Singh regarded the chemical service as an unprecedented act of bureaucratization. They held that 'no country in the world had followed the procedure adopted in the country for organizing scientific and industrial research.' (ICOM. Minutes, Vol. 5, p. 790.) The establishment of the chemical service created a new structure of research parallel to the already existing efforts of the universities. The service was also to be under the department of industries and thus under the direct control of governmental machinery. Malaviya and Singh warned against the devaluation of the universities and the consequent bureaucratization of research.

In his memorandum, Puran Singh, a scientist at the Forest Research Institute, contrasted the scientific communities endemic to the University, with the bureaucratic future of research in government control. He observed that in the west, scientific and industrial research carried on in government departments was not as popular or respected as that associated with universities. The university, he held, was subject to peer group control. 'A governmental official on the other hand has to keep a limited circle satisfied with his work, and his reputation once made in that circle runs little risk of being marred as he is safe under the protection of his official seat'. The university for Puran Singh evoked a sense of craftsmanship. 'In no country which encourages scientific research has it been possible for anyone to aspire to the dignity of a professor of the university without first having risen through the

ranks of student and assistant. . . . On the other hand, here one saw young men fresh from the university appointed direct to responsibilities of research and educational work and the stimulus for ever-increasing effort was in most cases lacking.' (ICOM. Minutes, Vol. 5, p. 789.) Singh did not deny the importance of state finance for research, but he held that the only function of the state, once it had identified an important problem, was to hand it over to competent men of science and provide them with every facility. Malaviya added to Singh's critique by observing that a distinguished chemist attached to a government department would develop more into an administrator and less a scholar. The chief chemist, he observed, would wield enormous power. 'At present a chemist who has completed an investigation is himself responsible for it and free to publish it. In the scheme proposed this freedom will be taken away from him. The judgement of the chief chemist will decide whether the result of any particular research work may or may not be published.' (ICOM. Report, p. 344.) Malaviya observed that this was incompatible with the existing nature of science as a specialized activity. 'Generally speaking the chief chemist will not be competent to pass a final judgement upon research relating to any branch other than his own. Dr Bose must be the judge of Dr Bose. It will be impossible for a man like him to work, when an official, however eminent he may be in his own particular subject, will have the power to reject or accept his work.' (ICOM. Report, pp. 344-5.) Malaviya reiterated that the control of research should not be left to the imperial department of industries, but to a science council elected by scientists working in the universities, colleges and other scientific institutions in the country.

Malaviya then set out to expose the contradictions inherent in the recruitment policy advocated by the Report. He observed that his colleagues had recommended that to the greatest possible extent junior appointments should be made from science graduates of the Indian universities and that the senior scientists required to initiate and direct research should be obtained on special terms from England, 'when such were not available here'. It was the practical implications of the qualifying clause that Malaviya proceeded to explore through a close reading of the Report. (ICOM. Report, p. 450.)

He observed, 'My colleagues recognize that a relatively small field of selection at present exists in India. They say, "as the

development of science teaching at the University proceeds and opportunity for technical training in India increases, we believe that the necessity of importing specialists will diminish".' (ICOM. Report, p. 350.) Malaviya added that the Commission qualified this by observing that 'it will be some years before it is possible to obtain the necessary staff in India'. The Commission thus had to rely for such recruitment on England. Malaviya observed that the Commission was aware that there would be post-War demands for chemical experts in England and consequently expect such experts would expect higher salaries than pre-War rates. Citing the Privy Council reports, Malaviya countered that Britain itself was facing a shortage of adequate chemical personnel and it would thus be unwise to rely on her for senior scientists. Proceeding further, he located a paradox in the Report. He pointed out that, though the Commission had recommended the recruitment of senior scientists from England, they actually wanted something quite different. What the scheme really suggested was not the recruitment of senior scientists from Britain but raw recruits who were expected to specialize after joining service in India. The Commission had recommended that the recruits should be obtained at as early an age as possible—preferably not exceeding 25 years. It added, 'If the young engineers whom we proposed to recruit are to develop into valuable men, then they should be encouraged after about three years service to take study leave.' (ICOM. Report, p. 361.) Malaviya felt that this was an insidious form of exploitation and cited as an alternative the recommendations of British expert before the Commission. 'No man should be imported into India unless he is a recognized expert in his particular line. He too should be engaged on short-term contract and made to understand he is being engaged and paid to teach our local men just as much as to introduce and carry on his work. The young man from abroad who is educated but inexperienced should not be brought to India and allowed to get his practice here.' (ICOM. Report, p. 348.) Malaviya advised that the whole scheme be dropped and Indian graduates recruited instead. 'Their training would be less costly, and they would serve the country for life, unlike the English graduates who would leave for higher emoluments elsewhere.' (ICOM. Report, p. 351.) Malaviya had no objection *per se* to the creation of the Indian chemical service or an industrial service. He merely felt that these institutions were premature. He insisted that

the material for such a service must be created within the country. Rather than a prefabricated chemical service, he advised the strengthening of the universities by developing the teaching of science and technology in them. He advocated a strengthening of their staff and equipment and an increase in the number of scholarships at schools, college and universities. It was only through such systematic, educational planning at different levels that the personnel to man the future chemical and industrial services could eventually be obtained. Malaviya felt that 'the institution of the proposed services should wait until this has been done. And in the meantime only such appointments should be made in the department of industries as are absolutely necessary.' (ICOM. Report, p. 354.)

VI

The industrial research laboratory as a formal organisation emerges from the structure of such a discourse. Encompassed within a philosophy of import-substitution industrialization, it is elaborated at two levels. At the first level an attempt is made to examine the general relation of science to technology within the industrial process and receives its most forceful presentation in the observations of Malaviya and Puran Singh. The second level involved an effort to elaborate how exactly science was to intervene in the technological process. This involved an attempt to understand the nature of its institutionalization through efforts to visualize an industrial research laboratory as a concrete ethnographic entity.

Malaviya and Puran Singh argued that science was not a primary factor in the first phases of industrialization. Basing their ideas on the Japanese experience, they offered a distinction between two classes of industries. The first and larger class consisted of those which could be started through the import of machinery and experts to act as the first managers. Unlike the second category, these industries demanded no original research. It was the emphasis on this class of industries that enabled Japan and Germany to achieve rapid development. The German and Japanese successes were as imitators rather than initiators through the adoption of instruments invented elsewhere. Based on his own personal experiences in Japan, Puran Singh developed this argument more elaborately.

This FRI scientist, who had spent three years in Japan, argued that Japan, like Germany, owed its success to imitation. Japanese policy was based 'on the wholesale transplantation of talent from other countries'. Japan did not wait for the birth of industry based on the resources of her own research. The Japanese obtained the services of the best engineers and chemists abroad in order to make a success of her industries. 'Model factories were erected, which in many cases became teaching grounds for a whole generation of entrepreneurs.' (ICOM. Minutes, Vol. 5, p. 788.) Puran Singh went on to observe that the industries that had survived and entrenched themselves in India were precisely those that had been established through a similar process. He cited in particular the Kanpur tanneries and the Tata steel works:

'The success achieved by the Cawnpore tanneries was obtained by bringing over a portion of England to India. Similarly a second Manchester has sprung up in Bombay and Swindons in miniature can be seen in the railway workshops all over the country. . . . The iron industry was established through the famous enterprise of the Tatas, by the wholesale transplantation of some of the expert steel makers of the world. The stimulus for steel making in India on the modern gigantic scale was received from America and hence the Tata works may be said to represent America in India. (ICOM. Minutes, Vol. 5, p. 786.)

Singh suggested that research alone could not provide the crystal seed of an industry. He admitted that it could provide new nuclei in a laboratory, but given the backward state of industrial development 'many of these wonderful discoveries would fail to develop and die unrecognized'. Singh argued that the remarkable discoveries made by research workers on such subjects as the contact process for sulphuric acid manufacture, the synthesis of indigo and the preparation of coal-tar products were achieved through the stimulus of a well developed chemical industry. He contended that the mutual reciprocity of technology and science came into full play only when industry had reached a certain stage of development and advocated as a result the immediate establishment of pioneer factories rather than the organization of scientific and industrial research. 'The real development of industries could not be attained by any amount of the organization of research or the creation of such posts as the Director of Industries, Directors General of Agriculture, Chemistry, Metallurgy etc.' (ICOM. Minutes, Vol. 5, p. 788.)

The rationale for scienticizing technology emerges at two levels, one bordering on ambivalence, the other lapsing into almost rhetorical enthusiasm. The first level deals with the whole question of the implications of synthetic chemistry for the natural indigo industry. The second unravels in a critique of the Swadeshi movement, particularly of that great nationalist fascination, the glass industry.

Lionel Heath, Principal of Mayo College of Art, Lahore, formulated the first issue in a pointed manner. He observed that the introduction of modern technology had created a nether world for the traditional craftsman whose training at the industrial school was inadequate to cope with the demands of modern technology. Yet this very process had alienated him from his hereditary calling. Heath illustrated his argument through a discussion of the dye industry. 'Vegetable dyes', he pointed out 'are no longer so beautiful nor so pucca as before. . . . The Punjabi has either lost the traditional methods of preparing and using these colours or has through the stress of commercial competition rushed the process and so has lost the beauty of the effect and the permanency of colour.' (ICOM. Minutes, Vol. 5, p. 268.) Heath held that 'while science cheapens and perfects production in the commercial sense, beauty suffers from this very quality of scientific production.' He cited as an instance 'the loss of power to reproduce the beauty of the Persian tile'. Heath realized that aniline dyes had come to stay, and claimed it was science that must go to the aid of the craft traditions. Yet he was afraid that modern science would imperiously ignore the individuality of the craft traditions. Pleading for a modernization of Indian craft traditions, Heath explained that the danger lay in all industries being cast into one western mould, and saw the Indian scholar trained in the west as the biggest threat to the craft tradition. 'The Indian returning after a year or two in England is only partially trained and has lost all sympathy for Indian workers and only strives to transplant Western styles and methods here without any desire to help in the improvement and preservation of Indian crafts.' Heath was against increased facilities for research and study in England, except for purely scientific work. 'What we do want is to keep the individuality of Indian industries and to do this we want to encourage the study and appreciation of what is best in them. There are none so ignorant of what is good in their own country as

the Indian students.' (ICOM. Minutes, Vol. 5, p. 269.) As an antidote, Heath suggested a series of travelling fellowships within the country to enable the student to study his own craft in other localities. He visualized his research institute more as a peripatetic school of visiting experts and exhibitions, providing expertise in marketing and using modern machinery to complement the traditional arts.

One attempt to aid the dyeing industry in this manner was made by F. M. Marsden, the dyeing expert in the Government of Madras. Marsden established a small dyeing school in Madurai, home of the *Sourashtras*, one of the larger dyeing communities. He rented a small room, which he fitted up as a laboratory, and dealt with a whole gamut of mundane questions 'which are the lot of works chemist in an English dye works'. Yet Marsden felt he was an interloper. He observed that the larger mills had their own chemist to tackle routine problems and 'in the country dye houses there was neither accommodation nor apparatus for experimental work to be done.' (ICOM. Minutes, Vol. 3, p. 153.) He realized that it was the marketing agents especially of the German dyestuff firms who were more effective than he was. The large dye houses seemed amenable to science, but the 'general attitude of the ordinary dyer was that he knew all there was to know about the trade'. Contrasting him to the western dyer, Marsden remarks 'The western dyer knows he cannot improve upon the manufacturers's methods, which are based on the investigation of highly trained specialists, but many if not most Indian dyers apparently cannot realize that the process given to them is as perfect as it is possible to make it, and proceed to make alternations and improvements and evolve what they term a secret process of their own; the only result is to increase the cost of dying and to impair the properties of the dye.' (ICOM. Minutes, Vol. 3, p. 154.)

Interestingly, Marsden did not question the rationale behind the method employed by the vegetable dye industry. When Holland asked whether it was possible to improve 'the primitive methods' adopted by the vegetable dye industry through further research, Marsden replied 'I do not agree that the methods which are in use are so crude

Holland: You say that there is nothing for the dyer to learn in that way in India, nothing to improve his method.

Marsden: It would improve slightly by his knowledge of the reasons for the selection of certain materials and processes being improved. But this is largely based upon profits and he would alter a method which is perfectly sound if he could produce his dye at a cheaper rate.

Holland: You say that his methods are the result of long evolution and are practically perfect.

Marsden: With natural dyes.

Holland: And you could not improve upon them no matter what you did.

Marsden: No, they have been improved in the west a little bit, with the aid of machinery and so on, but that is not research upon the natural dye itself. (ICOM. Minutes, Vol. 3, p. 159.)

Marsden viewed the diffusion of synthetic chemistry as demanding an altogether different organizational site. It necessitated a large dye house, a market with changing demands for colour, a generation of workers educated in the fundamentals of physics and chemistry and also a higher standard of consumption.

The ambivalence in science entering traditional industry stands in contrast to the appeals for science within the Swadeshi movement. We shall attempt to capture both the rhetoric and the analysis of the rationale for industrial research especially in the experiences of the Indian *ryugkusei*.

The Commission reported that the results of these scholarship schemes were inadequate. The schemes assumed that scholars could obtain easy access to works and factories abroad. 'In practice it was found that while educational institutions were freely opened to scholars, access to workshops was denied. The only exceptions were manufacturing iron works and small industries of no great consequence.' (ICOM. Report, p. 107.) Nagesh Chandra Nag testified that he was denied admission into the glass factories of the Chance brothers in Birmingham, despite a recommendation from Sir Alexander Pedler. B. M. Das of National Tannery confirmed this attitude. An alumnus of the University of Leeds and later a director of a CSIR laboratory, Das testified that even with the aid of his professors and the proctor of the University, he could not obtain entry into the tanneries of Yorkshire. (ICOM. Minutes, Vol. 2, p. 84.)

The evidence before the Commission also indicated that the administration of these fellowships was faulty and was the lack of objectives behind the enterprise especially worrying. Nicholson testified that the scholars had a very sketchy idea of why they were

sent. 'When I was in Japan I met a lot of young fellows who had come there and it was a positive fact that when I asked two young men of a new batch what they had come for, they were not able to tell me and a voice behind prompted them to say "weaving".' (ICOM. Minutes, Vol. 3, p. 417.) S. C. Deb, of Calcutta Potteries, testified that they had merely taken a set of theoretical courses but lacked workshop experience, etc., to translate the knowledge into practice. G. A. Mahamadi, the soap expert at the IIS, admitted that the fault was not of the Indian student alone. He contended that

in the absence of any arrangement to get practical training in the factories which is invariably insisted upon by every student and usually declared impractical as a rule, the student perforce joins the university or polytechnic, puts in two or three years, returns to India with the principles underlying the manufacturing process of his industry, but no practical experience. The result is that he is no good for industries because there is no need for such a scientific man in them, as they are at present. They want a man who should be of practical use to them in enabling them to make a thing which they could sell, and not one who has got a number of theories and not very much sure which one of them is the best. (ICOM. Minutes, Vol. 3, p. 557.)

The rationale for industrial research unravels through the descriptions of these scholars. Its rhetoric emerges in the evidence of Nagesh Chandra Nag. A Fellow of the Institute of Chemistry, recipient of the Elliot Prize of the Asiatic Society for his researches on titanium, Nag lectured at Agra College. He confessed before the Commission that he was not able to follow up on his early researches as he had to deliver 24 lectures a week. (ICOM. Minutes, Vol. 1, p. 296.) Nag argued before the Commission that to promote industrial research in India it was absolutely necessary that there should be better co-ordination between university training and actual manufacture. By this he meant that 'wherever possible, a science department or college should be expected to manufacture certain materials of everyday use, so that the students may be acquainted with the actual process of manufacture,' and went on to testify that he had personally 'prepared pencils, manufactured burners, fitted my whole laboratory with water and gas pipes, manufactured foot-bellows at one-fourth the price'. 'Such efforts', he stated, 'make science a vital force'. Nag complained about 'the want of confidence in the analytical reports

and results' submitted by Indians and asked 'the government to come forward and help the struggling investigator' (ICOM. Minutes, Vol. 1, p. 295). The Commission's impatient cross-examination of Nag in this context reveals the naïveté and the zeal of the Swadeshi plea for industrial research out-running the understanding of the mechanics of translating science into technology.

Holland: You say that you have personally experienced the want of confidence in the analytical results submitted by Indians. Is there any instance you could give as an illustration of that.

Nag: I analysed wolfram from Jodhpur, and I gave my results to the revenue member and he would not believe me.

Holland: But that was an Indian member of the Durbar. How is the Commission going to bring about reform of this kind?

Nag: If we Indians are given a chance to analyse certain things and our reports are given publicity and action taken on our reports, then I think people will understand that we can do some work of value. Now somehow or other Indians do not command that amount of confidence. (ICOM. Minutes, Vol. 1, p. 297.)

Nag and his colleague Salig Ram had conducted experiments on the production of bleach liquor to disprove 'the gospel truth' about the unsuitability of the Indian climate for the production of certain materials.

Nag: ... We went to the Lucknow Paper Mills and prepared it. They did not believe it was possible to prepare this in the climatic conditions of India.

Holland: Did you put the matter before the director of industries?

Nag: I think the director of industries knows it.

Holland: Was the matter put definitely before the director of industries so as to lead him to suppose there was a definite proposition to follow up?

Nag: I have not done so, but it was published in some local newspapers.

Holland: No one can take notice of a local paper in the matter of technical and scientific results. You must publish in scientific journals which are read by men who are capable of understanding and forming an opinion in the matter.

Nag: Before we go to a scientific society our work must be thorough and before work can be done thoroughly we must have sufficient time and material to work on.

Holland: In other words your results are not thoroughly done?

Nag: They are thoroughly done as far as the preliminary results are concerned.

Chatterton: Did you put a business-like estimate of what the whole thing would have cost on a bigger scale?

Nag: I told them to get 25 or 50 cells...

Chatterton: They are not technical people and you must give them some estimate of what it would cost.

Nag: We wanted them to spend only Rs 200 or so.

Chatterton: Have you seen in some mills in India, bleach liquor prepared by electrolysis?

Nag: No.

Chatterton: Then why not see what is actually being done?

Nag: I was told that they could not prepare it.

Chatterton: If they called you as an expert would you not be expected to know such processes were at work in the country?

Nag: I saw some advertisements. They said it was rather expensive...

Chatterton: Have you heard of the Empress Mills at Nagpur and the Buckingham Mills at Madras and the Titagarh Paper Mills? Do you know whether they use bleach?

Nag: I have not heard anything about them.

Holland: You say that the statement that the Indian climate is unsuitable for the production of bleach should not be taken as gospel truth. We all know it is not gospel truth. Bleach liquor is prepared constantly in many mills in India, for example the Empress Mills at Nagpur, the Buckingham Mills at Madras and there is nothing mysterious about it (ICOM. Minutes, Vol. 1, p. 298).

The other proponents of industrial research were more durable before the ruthless cross-examination of the Commission's technocrats. They emphasized the constraints of colonialism, but also realized that Swadeshism had paid an enormous bounty to technological incompetence. It was the self-criticism of these experts that generated the first systematic charters for industrial research. More particularly, it was the critique of Swadeshi fascination for the glass industry that brought home the importance of science for technological process.

The glass industry was the Robert Bruce of Swadeshi technology. Each failure had generated a series of new efforts, which in turn had succumbed for want of information regarding location, raw materials, blast furnaces and markets. The Commission emphasized that the industry even in its simplest form was highly technical and raised a matrix of problems which no single

individual could cope with. Holland warned the Paisa Glass Fund that the recruitment of a single engineer from abroad was woefully inadequate to solve the problems of the industry. 'These practical men were accustomed to working under conditions different from those prevailing in India, and their technological skill was inadequate to solve the problems presented by the new country.' (ICOM. Appendix E, p. 366.) At every stage of its production the glass industry demanded the scientific investigation of an interdependent team of experts. Out of the difficulties of the Swadeshi efforts in glass, ceramics and leather, the first ethnographic attempts to visualize the industrial research laboratory as a concrete entity arose. The models of industrial research propagated in the Commission's Report encompass four different sites of activity.

In the first, the university itself assumes the responsibility of scienticizing technology. Amongst its major proponents was Nilratan Sircar, who argued that 'the only proper institution from which research work could be expected and has emanated in all countries is the university.' (ICOM. Minutes, Vol. 2, p. 340.) Closer home, the particular institution, Sircar had in mind was the University College of Science. The second set of advocates argued that the modification of technology can only be brought about at the site. Here technology as represented by the pioneer factory assumes the task of incorporating science into the technological process. The third alternative offered the conception of industrial research as an interface embodied in a network of reciprocities, a circulation of problems and personnel for mutual benefit. Rai Sahib Pannalal, the glass industrialist, captures this eloquently:

Wherever there is the smoke of the factory chimney, there are unsolved, exasperating, vitally important manufacturing problems—problems in glass, porcelain, starch, tanning, paints, iron, oil and metallurgical products—problems which arise whenever man deals with substance. It seems clear that these problems can be best answered by combining practical knowledge and the large facilities of the factory with the new and special knowledge of the universities, and by making this combination through young men who will find therein their success and their opportunity. It lies in giving the manufacturer (or his patron, the Government of India) the privilege of founding in the university, a temporary industrial fellowship for the investigation of a specific problem, the solution of which would mutually benefit both manufacturer and

public. When, therefore, the university accepts from the manufacturer the foundation of an industrial fellowship, it not only provides an expert, intensive attempt to solve the problem by the application of the newest of new knowledge but it provides for industry, a 'good man', whom the industry would do well to cherish. (ICOM. Minutes, Vol. 5, p. 156.)

The fourth attempt, which is the most detailed, visualized the industrial research laboratory as a distinct organizational vehicle for import substitution industrialization. Presented in the evidence of Das, Deb and Simonson, it becomes more a catalogue of goals than an analysis of the processual nature of industrial research as an activity.

The most ethnographic attempt to visualize such a laboratory was by S. Deb of Calcutta Pottery. Stemming from his experiences as a manager and based on his visits to Japan in 1904 and 1909, Deb provided an annotated catalogue of the 'vast and varied functions of this Central Institute' where 'the best brains of the land might be employed to solve not questions of academic interest but questions confronting industry.' (ICOM. Minutes, Vol. 2, p. 45.)

According to Deb, the institute was to gather, arrange, and classify the resources—agricultural, forest and mineral—available for development in an industrial museum.

When the Calcutta Pottery Works was established in 1907, China clay was forthcoming from the hills at Rajmahal. I wanted to manufacture porcelain, but I had no felspar. I was at a loss to know what to do. The records of the Geological Survey of India could not help me materially. They could not enlighten me as to the possible source of a constant and economic supply of felspar and at last I was obliged to set out accompanied by a geologist on a felspar finding expedition. After a fortnight's very hard work to which I was quite unused, we were fortunate enough to find a good deposit of felspar, suitable for the manufacture of high class porcelain. (ICOM. Minutes, Vol. 2, p. 48.)

Deb emphasized that the failure to explore the economic feasibility of raw materials was one of the great drawbacks of the Swadeshi industries.

The second function of the institute was to establish by experiment on raw materials available in the country the feasibility of manufacturing articles hitherto imported in large quantities. Deb cites as an example his own experiences in the porcelain testing laboratory at Kyoto, Japan. British 'iron stone china' (a

class of porcelain ware), had flooded the Japanese market despite heavy freights and high tariff. The government took up the matter and asked the director of the porcelain testing laboratory to investigate the possibility of import substitution. Experiments in manufacturing "iron stone china" out of Japanese raw materials began in earnest. 'We were given dozens of 'iron stone china' plates to break and scrape the thin layer of glaze on them; compositions of "iron stone china" were found out by analysis and suitable indigenous raw materials were selected and "iron stone china" was manufactured in the laboratory. I remember a pottery manufacturer, named Matsumara, who took up this new line'. (ICOM. Minutes, Vol. 2, p. 46.) Deb reported that by 1909 the factory had not only displaced British iron stone china but completely flooded the Calcutta market.

The institute would issue regular reports of all the researches carried out, both in English and the vernacular. Deb complained that government monographs were a sealed book to 99 per cent of the public. It would also permit persons interested in any industry to investigate and carry out special researches on their own lines in its laboratories and workshops. Deb cited his own experiences in a Berlin laboratory where he was allowed to carry out special researches on porcelain for 250 marks a month. Further, the institute was to hold regular exhibitions of its products to be displayed alongside imported articles with statistics showing differences in price, quality, etc. It was also to conduct periodic lectures with experiments and lantern slides. (The model was the Ecole Polytechnic in Paris where the best experts from industry were invited to deliver periodic lectures.) The institute would have a department of rapid commercial analysis to determine suitability for manufacture, a testing department where consumer articles, medicines and instruments would obtain guarantees of quality. Finally, it was to consist of an analytical laboratory, a testing department for manufactured products, a workshop fitted with modern appliances, a foundry capable of supplying all the needs of the laboratory and testing department 'so the whole thing would be self contained', with a well equipped library containing scientific and technical books in all the principal languages of Europe and portfolio of plans and designs of the best industrial establishments of the world and catalogues of machines with lists of firms manufacturing them. It would also incorporate a patents

and trademarks department. The board of the institute would have representatives from the government, business and science. The director and the two assistant directors would be ex-officio members. Deb wanted the director to be a foreigner 'with liberal scientific education, practical and business like, social and sympathetic, with a knowledge of French and German. . . . If these qualities are difficult to find in one man a directorate may be formed of persons as is usually done in Germany.' (ICOM, Minutes, Vol. 2, p. 47.) Under him would be two Indians, as assistant directors; one, a scientific in charge of the laboratory and the other a practical businessman in charge of the commercial museum. Deb wanted the laboratory to be located in Calcutta as it was the premier port of the country with proximity to coal, waterways and railways.

Deb's scenario was a magnificent list of props and personae, a catalogue of the elements, without the structure of what constituted the industrial research laboratory. As the plot elaborated, the Commission began to confront the tensions implicit in the establishment of industrial research. It confronted two of them in particular, that of the location of the laboratory and the problem of payment for consultancy. The Commission's Report eventually offered elusive half-hearted answers to both.

The controversy over the location of this central laboratory begins with a critique of the major centre for industrial research, the Indian Institute of Science, Bangalore. The Bengali chemist, P. C. Ray, condemns the institute as a white elephant with 'halls as big as those in Buckingham Palace' and 'located in place quite out of touch with existing industry and beyond the pale of public opinion.' (ICOM. Minutes, Vol. 2, p. 42.) Deb coupled the Bangalore Institute and the Imperial Institute at London as being distant and incapable of arousing any interest in the Indian manufacturer. (ICOM. Minutes, Vol. 2, p. 47.) The geologist Ghose stated that the Institute of Science had not achieved the objects of its illustrious founder. He added that the 'leading colleges in Bengal, inspite of their extremely economical organization, produce and retain a greater number of scholars who are inspired by the brilliant achievements of professors of international reputation. Had the IIS been located in Bengal it would have attracted a larger number of brilliant students.' (ICOM. Minutes, Vol. 3, p. 22.)

The responses of the Institute's scientists to the Commissions critiques varied with the departments. Alfred Hay of the electro-technology department believed that his department functioned as a university department, emphasizing that, while the Institute had the equipment for the standardization and testing of apparatus, the possibility of it becoming an NPL for India was distinctly remote. The professors in the three departments of chemistry were more concerned with the division of spoils in the boom period to come and preoccupied with their relations with large-scale private industry. Their reactions to the Swadeshi movement is captured in Fowler's answers to the Commission.

Low: Have you had any direct inquiries from the proprietors of small industries of the Swadeshi type?

Fowler: Yes.

Low: How are they dealt with? Are fees charged in respect of these inquiries?

Fowler: As a rule we suggest a modest fee and that has sometimes stopped inquiry.

Low: You are that there has been a constant cry on these people's part for government expert help being readily available to proprietors of small struggling industries, who have neither the knowledge nor the means to get research done in a big way like the larger industries, and it is certainly up to us to provide some means for these people to obtain such information. Whether an institute like this is the best place to apply, is another matter. In a general case, such an inquiry would, I take it, be recognized as a public one.

Fowler: I am not sure. Don't you think that that which you get for nothing, you value every little?

Low: Very often these people cannot pay.

Fowler: Then ought they to be engaged in industry? (ICOM. Vol. 3, p. 344.)

The critiques of the Swadeshi experts were upheld in general terms by the Commission. But behind it was the nagging doubt that the claimants had actually stated that India needed a research laboratory and that it should be located in Bengal. Countering this was the memorandum of the Institute of Science which made a plea for Bangalore as the nucleus for a central laboratory for India.

This problem of location and the possibility of accounting for vested interests was explicitly discussed by Holland and Simonsen,

Professor of Chemistry at Presidency College, Madras. In his initial statement to the Commission, Professor Simonsen claimed that the central laboratory should be near an industrial area, preferably Calcutta or Bombay. He felt that this would still leave the Bangalore Institute with a large sphere of activity. It was the President of the Commission, Thomas Holland, who made Simonsen confront the problem of the politics of location. Holland said, 'If you place the central laboratory in any place it must be influenced by the local colour. For instance the GSI is at Calcutta. Consequently Calcutta is likely to have more vested interests at work than in any other presidency.' (ICOM. Minutes, Vol. 3, p. 105.)

When Simonsen still insisted on a centralized laboratory, Holland suggested, 'Your proposal may be good from the scientific point of view but from the administrative point of view there may be difficulties. Considering the size of India and great variation in the local colour do you think that compromise is possible?' 'Don't you think it would be advisable to recognize local and vested interests to the extent of not having one central laboratory but something like three headquarter laboratories for three well-defined versions of chemistry?' (ICOM. Minutes, Vol. 3, pp. 104-5.) Holland suggested the possibility of locating the division of agricultural chemistry at Pusa, the department of organic chemistry at the Forest Research Institute at Dehra Dun, and the department of metallurgical chemistry at Calcutta, or near the iron and steel belt. Simonsen insisted that such a division was injurious to scientific research which demanded collaboration with cognate subjects. In the additional evidence presented to the Commission, Simonsen reconsidered the whole question of the location of the central laboratory on the basis of three main features: (1) utilization of existing facilities; (2) climatic conditions; (3) proximity to an industrial centre.

In terms of utilizing and extending facilities, he believed that the Bangalore Institute had the most adequate nucleus for industrial research. Bangalore also scored in terms of climate. Simonsen, however, felt that Bangalore had a distinct disadvantage in terms of its distance from industrial centres. But he argued that 'the comparative isolation in Bangalore would ensure that the laboratory would not be influenced by local surroundings but would exhibit an equal willingness to attack problems formulated by any

part of the Indian empire'. After careful consideration Simonsen recommended the Institute as the site for the central research laboratory, advising that it would be possible to commence work immediately as the laboratory had a highly trained staff readily available. (ICOM. Minutes, Vol. 3, p. 113.)

The second major issue that confronted the Commission was 'the old dilemma of adjustment between academic and commercial activities.' (ICOM. Minutes, Vol. 3, p. 545.) The problem arose out of the controversy over private consultancy by scientists. The scientists in general argued for such a system, with Simonsen contending that the existing government rules, which prevented officers from undertaking private work, were regressive. Simonsen admitted the dangers of commercialization but believed that advantages like continuous interaction with new problems of research and the ability to find employment for one's students outweighed the disadvantages. However, the question soon became a procedural one concerning the nature and distribution of payment for such work. Watson, the Professor of General Chemistry, believed that the problem could be eliminated altogether by stipulating that payment be made to the Institute, as the professors were paid a salary. His observations bring out the dangers of commercialization: 'The Mysore Government has asked us to investigate some refractory materials. I admit that I know very little about refractory materials, and I can only apply general scientific principles. There is a man in Bombay who has spent his life working on refractory materials. If he was at the Institute he would naturally take the work up. Supposing though, we were both at the same institution and someone asked me if I would undertake an examination for a fee; I might be tempted to do it myself instead of handing it over to a man who could do it. In that I think there would be a loss of efficiency.' (ICOM. Minutes, Vol. 3, pp. 553-4.)

The scientist nevertheless insisted on the importance of such incentives and merely advocated a rationalization of it. Simonsen suggested a pro-rata division of fees on the following three grounds:

- (1) If fees were paid to a man or men concerned it would place a large premium on applied as opposed to pure science. This would not but prove injurious since pure science is the basis from which applied science develops.

- (2) The solution of the problem might be due to the work of several men and it would be difficult to divide the fees amongst them.
- (3) Unless a pro-rata division is made, there is likely to be considerable difficulty in running the department and render the allotment of research by the chief chemist a matter of great difficulty. (ICOM. Minutes, Vol. 3, p. 103.)

One other possibility suggested to cushion the impact of commercialization was the creation of research corporation as an innovative buffer. The corporation was intended to serve the needs of those scientists who had patentable inventions and interested in their further development but 'who were disinclined to undertake such development themselves or place control in the hands of private interest.' (ICOM. Minutes, Vol. 3, p. 547).

VII

The recommendations of the Holland Commission were never implemented. In fact, by 1924 there was a complete reversal regarding the commitment to industrialization. The Board of Scientific Advice established in 1902 to provide commercial and industrial intelligence was dismantled. The only other institution oriented to industry, the Indian Munitions Board, created as separate department of the Government of India, restricted itself to the logistics of war materials and proved indifferent to the problems of scientific research or the establishment of new industries. The one tangible result of the recommendations of the Holland Commission was the establishment of another bureaucratic structure, the department of industries. As Meghnad Saha was to later remark, 'from 1924, due to some mysterious reason, the Government of India dropped all ideas of developing the natural resources of India and concentrated purely on agricultural research and agricultural industries. What high agency was responsible for this policy was not known, but India was henceforth condemned to grow potato and paddy'. (Saha, 1940(1), p. 502.) This policy of the British government in emphasizing agriculture over industry, and the anti-industrialism of Gandhi and a significant section of the Congress brought about as a reaction one of the most vigorous pressure groups for heavy industrialization and scientific research—Meghnad Saha and the

Science and Culture group. *Science and Culture* added the poetics of planning to the Commissions discourse on industry. It is to this that we shall turn in the next chapter.

CHAPTER 4

THE RISE OF INDUSTRIAL
RESEARCH III

I

To his colleagues in physics 'the name of Meghnad Saha will always be associated with the theory of thermal ionization and its application to stellar spectra.' (Kothari, 1970, p. 49.) An appreciation of Saha, the physicist, is beyond the confines of this chapter. We can at best cite the opinions of some of his peers. Otto Sturve, himself a distinguished astronomer, believed that Saha's work inaugurated a scientific breakthrough comparable to that which occurred when Fraunhofer and Kirchoff laid the foundations for a spectroscopic investigation of stellar bodies. (Kothari, 1956, p. 317.) Roseland in his *Introduction to Theoretical Physics* commented that much of the work in astrophysics was basically an extension or a refinement of Saha's ideas. While this chapter will not dwell further on Saha's contributions to physics, it will try to understand his life as an expression of science in the pursuit of the sociological imagination. We shall attempt to do so by locating the biography of the man within the history of the age.

Meghnad Saha was born on 6 October 1893 in a poor family of petty shopkeepers in the village of Seerotali in Dacca. (Kothari, 1970, p. 50.) The little village possessed no school of its own and the nearest school teaching English was seven miles away. The young Saha was able to attend this school mainly through the generosity of a local doctor who provided him with free board and lodging. In 1905, Saha joined the government collegiate school where he had his first taste of politics. The Partition of Bengal drew into its vortex a generation of student agitators and Saha was among those who boycotted the Lieutenant-Governor's visit to the school. Under the terms of the Carlyle circular which proscribed such participation, Saha was forced to surrender his scholarship.

He moved to a private institution, the Kishorilal Jubilee School and it was here that he appeared for the entrance examination to Calcutta University, standing first among the candidates from East Bengal. After passing his intermediate from Dacca College, Saha joined Presidency College, Calcutta for his B.Sc. degree. Presidency College at that time possessed an extraordinary galaxy of students who soon became leading figures in Indian science. Many of them were to later form the nucleus of one of the most remarkable networks in Indian science, the editorial board of the magazine, *Science and Culture*. Among his contemporaries at Presidency were S. N. Bose, later to become a Fellow of the Royal Society and one of the most persistent advocates of science education in the vernacular; Nikhil Ranjan Sen, the mathematician; J. N. Mukherjee who became Director of the Indian Agricultural Research Institute; J. C. Ghosh, who became Director of the Indian Institute of Science, Bangalore and member of the Planning Commission. Nilratan Dhar, the chemist, and Prasanta Mahalanobis, the physicist, who was to establish an outstanding scientific institute, the Indian Statistical Institute, were two years his senior. Saha, Ghosh, Mukherjee and Dhar were residents of Hindu Hostel at Presidency College. It was while staying at the hostel that Saha became acquainted with Bagha Jatin, the terrorist. Subhash Chandra Bose was Saha's junior by three years and two of Bose's elder brothers were Saha's classmates.

Saha originally intended to join the Indian Finance Service but the government refused him permission because of his association with the terrorists. He then decided to pursue a career in research. In 1916 Asutosh Mukherjee invited Saha, Ghosh and S. N. Bose to join the University College of Science as lecturers. Saha's first original contribution, 'On Ionization in the Solar Atmosphere' appeared in *Philosophical Magazine* in 1920. He went abroad, to Germany and England, for a short while and returned in November 1921 as Khaira Professor of Physics. In 1923 Saha joined Allahabad University and devoted the next fifteen years to transforming his fledgling department into an outstanding centre for physics. Several of his younger colleagues and students—D. S. Kothari, R. C. Majumdar, P. K. Kitchlu—were to later migrate and create at Delhi University another outstanding centre for physics. (Kothari, 1970, p. 57.) While at Allahabad, Saha was

elected a fellow of the Royal Society. It was towards the end of his stay there that he became concerned with wider professional issues. In 1932 he participated as President of the U.P. Academy of Sciences and followed this up by working towards the establishment of the National Institute of Sciences in 1934. During these years Saha became increasingly preoccupied with the problem of flood control and consequently with the efficient utilization of energy in society.

In 1923 P. C. Ray had assumed control of relief operations in Bengal and chose as his officer for publicity, Meghnad Saha. Their participation in these activities affected both Ray and Saha but led them to two entirely different social philosophies. After the relief operations, Saha became obsessed with the need to scienticize the problem of flood control. His early efforts at analysis were published in *Modern Review* and in the *Festschrift* for Ray in 1930. In this essay Saha made a plea for a river research laboratory for India. By 1938, as President of the National Institute of Sciences, Saha had convened the first national seminar on river-valley planning and invited Jawaharlal Nehru to preside over it. Saha's speech at the seminar was a brilliant survey of cities as river-valley civilizations. It was also the first systematic attempt by an Indian scientist to visualize technology within a broader socio-ecological context. (Saha, 1938, (1), p. 36.)

The problem of river-valley planning assumed importance when the British took over the responsibility of maintaining and extending the irrigation systems in India. Saha estimated that the British spent approximately Rs 150 crores on these activities and acknowledged that the water-scarce areas of Punjab had benefitted as a result. But he added that in Bihar and Bengal these irrigation works had been virtually counter-productive. The engineers entrusted with the planning of bridges and embankments were not familiar with the conditions of these provinces and transferred mechanically the lessons obtained from Punjab to Bengal. 'The people of Burdwan have always complained that the railway embankment ruined the Burdwan division. It changed the course of the rivers in this division and deprived the land of fertilizing silt. The Burdwan division became a victim of malaria which between 1860-70 wiped out half her population.' (Saha, 1938, 1, p. 43.) This tragedy could have been avoided if the problem had been scientifically conceptualized and studied with

simulated models in a river research laboratory. Saha echoed the words of the British engineer Francis Spring that 'the appointment of a river commission for the organized study of the great alluvial rivers would be a service to civilization and an act worthy of the state.' (Saha, 1938, (1), p. 40.) In 1944 the Bengal River Research Institute was established. Saha's preoccupation with flood control also drew him to a remarkable socio-technical experiment—The Tennessee Valley Authority (TVA). The TVA, a unique exercise for capitalist America, was a gigantic programme of flood control, navigation and power development; a technological exercise that called for the corresponding institutional innovation of regional planning. It was mainly due to Saha's efforts that Voorduin, an expert from TVA, was invited to India and it was the latter's report that provided the basis for a similar experiment—The Damodar Valley Corporation (DVC).

In 1934 Saha helped establish the Indian Science News Association with a gift of Rs 1000 from Sir Upendranath Brahmachari, whose researches had found a cure for Kalaazar. The Science News Association founded a magazine, *Science and Culture*, which was to present some of the most forceful arguments for a society based on the scientific method. The speeches at the inaugural session of the Association at University College of Science and the first editorial emphasized the basic purpose of the journal. The editorial remarked, 'it is obvious to every thinking man, that India is passing through a critical stage when over the cultural foundation of her ancient civilization, a structure of modern design is being built. It is necessary that at such a juncture the possible effects of increasing the application of the discoveries of science to our national and social life should receive careful attention'. (Saha, 1935, p. 2.)

The editorial also emphasized the crucial necessity of confronting western industrial civilization. 'This civilization differs from all other ones in the enormous increase in scientific knowledge and the intensive application of scientific discoveries to all branches of scientific activity.' (Saha, 1935, p. 3.) Then, referring to the nature of the Indian response, it remarked that

amongst our leaders [are] a considerable number incapable of seeing the great and inevitable part which the new age of technic will play in India's destiny. In vernacular literature one frequently comes across overdrawn pictures of the imaginary good old days when nobody was supposed to

have anything to complain of and a tendency to attribute all the present troubles of the world to the evils of science. One of the solutions offered is the total rejection of all modern techniques of manufacture, and the necessities of life based on the application of scientific knowledge. It is a fact that a large section of the masses have suffered terribly from the effects of industrialism as practised in India today, which amounts to the exploitation of the masses for the benefit of the few.' (Saha, 1935, p. 3.)

The editorial emphasized that the success of Gandhianism lay precisely in the genuine sympathy it expressed for the victims of such a selfish industrialism but maintained that 'we do not for a moment believe that better and happier conditions of life can be created discarding modern scientific techniques and reverting back to the spinning wheel, the loin cloth and the bullock cart. (Saha, 1935, p. 3.)

During the next twenty years *Science and Culture* devoted itself to its two fundamental objectives—the interpretation of science and its popularization, and an advocacy of the full-scale application of science to bring about a technological revolution. The 2,100 articles and 4,600 notes published till Saha's death in 1956 were devoted to an attack on 'Gandhian regressiveness' and to elaborating the intricacies of an alternative vision of a scientific industrial society.

To the Science and Culture group, industrialization in the twentieth century presupposed two imperatives: first, the necessity of total planning, and secondly, the necessity of scienticized technology. The whole gamut of debate on industrial research was an attempt to combine the two great institutional innovations of the nineteenth and twentieth centuries. In the memorable words of Whitehead, the outstanding invention of the nineteenth century was the 'invention of invention' itself. (Whitehead, 1938, p. 117.) In *Science in the Modern World* Whitehead remarked that 'to understand our modern epoch we can neglect railways, telegraphs, radios, spinning machines and synthetic dyes. We must concentrate on the method itself. (Whitehead, 1938, p. 118.) Whitehead emphasized the crucial distinction between science and technology. He insisted that scientific knowledge was not an abundant store house from which one readily helped oneself. 'An intense period of imaginative design lies between them. One element in the new method is how to go about bridging the gap between a scientific idea and its ultimate product.' (Whitehead, 1938, p. 118.)

If the institutional integration of science and technology embodied in the industrial research laboratory was the major institutional invention of the nineteenth century, planning, as the Webbs have pointed out, was the major institutional invention of the twentieth century. We shall now proceed to analyse Saha's perception of the two.

Ever since the establishment of the U.P. Academy of Sciences and the Indian Science News Association, Saha became increasingly preoccupied with the problems of industrialization. The transition from the professional to the political is best captured in his own words: 'Scientists are often accused of living in an ivory tower scarcely troubling their minds with realities, and apart from my association with political movements in my juvenile years I had lived in an ivory tower up to 1930.' (Sen, 1956.) Saha believed that the immediate cause of his entry into the political scene was Kailash Nath Katju. When Katju was industries minister in U.P. in 1936 he was asked to inaugurate a match factory. The minister gave an enthusiastic address hailing the factory as the first step towards large-scale industrialization. The speech irritated Saha, even confounded him. He was astonished that Katju had no conception of the requirements or implications of industrialization. The minister's ideas were representative of a whole generation of Congressmen whom Saha viewed as landlubbers suddenly summoned to pilot ships on an ocean. He decided that the time had come to approach the problem more scientifically and Meghnad Saha, the astrophysicist, tried his hand at economics.

He began by consulting the year books published by the League of Nations, especially by its department of labour. This compendium contained a number of tables on the production of commodities in different countries. (Saha, 1944, p. 100.) Saha tried to generate a comparative index of the income of different countries of the world but was unsuccessful in obtaining any kind of quantitative index. However, he felt that an appropriate index might be obtained by calculating energy consumption and assuming that the wealth of a country was directly proportional to the energy consumed. He was more at home with this; energy outputs, he felt, were closer to science. He measured energy by aggregating the work done by men and domestic animals and also that done by engines with the aid of various fuels—thermal, hydroelectric

power, etc. He then calculated the per capita output of every country. The energy index for Britain was 2000 and for the USA 2500. There were no comparable statistics available for India. But government estimates stated that India used 3500 million units of electricity, which came to about 9 units per capita. After adding the energy production from coal and men and animals, Saha estimated that the average energy consumption could not be more than ninety units per year. Such an energy index was equivalent to that of Europe in the Middle Ages. (Saha, 1944, p. 101.) What Saha then tried to do was to find an institutional system that would guarantee not only an efficient production of energy but also an equitable distribution of it. During a symposium on India's power supply, he attacked the private firms which had been granted licences for the generation and supply of electricity. Despite the improvements in the technology which enabled a ton of coal to produce four times as much energy as it did two decades earlier, there was no corresponding reduction in the rates charged. The Calcutta Electric Supply Company produced electricity at a cost of 0.35 annas per unit for domestic purposes. The charges were nearly six times higher than the cost of production. An analysis of British supply companies showed that nowhere was the ratio more than two or three.

Meghnad Saha found his model of a high energy society in Soviet Russia. What impressed Saha and the Science and Culture group was that Russia before World War I was as backward as India, a poverty-stricken agricultural country, where industries were primitive and power a luxury. Russia was without knowledge of her power resources, without experts and technicians. It was then that Lenin inaugurated his schemes for planned industrialization and by 1935 Russia was producing 300 units per capita. In a series of articles on the Soviet experiment, Saha emphasized that Lenin realized clearly that unless Russia was placed at a different technical level, the growth of the national economy and the establishment of communism was impossible. (Saha, 1938, (i), p. 49.) Lenin suggested electricity as the technique appropriate for a socialist economy. In fact, he stated that 'communism is Soviet power plus electrification, for without electrification progress of industry is impossible'. Within sixteen years Lenin's plan, which even the futuristic Wells conceived as utopian, helped Russia pass from an agricultural to an industrial stage. Saha's perception of the

GOELRO plan has to be understood in detail.

What impressed Saha about the Soviet experiment was that when the Supreme Council of the Soviet adopted Lenin's resolution, it was the USSR Academy of Sciences and not a committee of bureaucrats which was requested to formulate the plan. The chairman of the planning commission, which comprised over 250 scientists and engineers, was G. M. Krzhizhanovsky.¹

It was the relation between the scientist and the politician in Soviet Society that fascinated Saha and the Science and Culture group. They saw in Soviet Russia a society based on the scientific method which had achieved an unprecedented technological revolution from a paleotechnic to a neotechnic civilization. The editors of *Science and Culture* drew two further conclusions from their studies of industrialism. One was regarding the relation between industrialization and scale, where they felt that the movement toward collectivization or cartelization was inherent in industrialization. 'It was dictated by technical advances whose full benefit could only be derived if they were used on a large and comprehensive scale.' (*Science and Culture*, 1942, ii, p. 146.) Saha emphasized that the technological revolution was going to be a large-scale one and that 'nothing could stop it except a return to handicraft methods of production—a method as we have been at

¹G. M. Krzhizhanovsky, a colleague of Lenin since his under-graduate days, was an electrical engineer, one of the few scientists who saw no tension between professionalism and politics. Rather, he saw in the October Revolution the social prelude to the technological revolution, based not on steam but electricity. A social visionary, he shared with Lenin a belief in a society based on the efficient utilization of energy and later even coined an index for it. In the debates that took place in post-Civil War Russia, Krzhizhanovsky articulated his vision of the technological society. What impressed Saha was Lenin's support for him and the Academy of Sciences. Krzhizhanovsky argued against Trotsky's view of planning which suggested the army as the basic model for society. What Russia needed was to transform the masses into an army of labour power. Arguing against the idea of a labour force, Krzhizhanovsky suggested that the machine was so productive that even Russia's pre-War stock of 13 h.p., if worked in two shifts, could do as much as 200 million manual labourers, or 3½ times the working population of Russia. In later debates he also attacked those who emphasized agriculture for underestimating the technological potential of large-scale rationalized industry. Lenin was extremely enthusiastic about Krzhizhanovsky's scheme for electrification. By 1921 Lenin called electrification the second program of the Party. Krzhizhanovsky's commission for electrification (GOELRO) became Russia's first planning body.

pains to prove is limited in its potentiality, it can only lift a people slightly above poverty and medieval misery.' (*Science and Culture*, 1942, ii, p. 145.) Saha believed that when Russia was confronted with this choice her leaders deliberately 'chose the cold logic of technology over the vague utopias of Tolstoy.' (*Science and Culture*, 1943, i, p. 316.)

The second conclusion related to what Saha called a misconceived emphasis on agriculture. He argued that a survey of Indian soil showed that 'an acre of Indian soil produced four times less crop than in any other country. Further, no scientific attempts had been made to recoup the soil which was deficient in nitrogen and potash. An increase in agricultural production of even 20 per cent would require an estimated six million tons of ammonia. Fertilizer requires electrification and we can consume 10,000 to 20,000 million units on a fertilizer unit alone'. What Saha was arguing in effect was that higher productivity in agriculture required a planned industrial infrastructure to provide basic inputs like electricity and fertilizers.

The Science and Culture group believed that the Soviet model was ideal for India and set about transplanting it. They extricated the following elements from the Soviet model. First, an emphasis on high energy societies which demanded planned industrialization; second, the necessity of scientized technology, institutionalized through industrial research. Third, the prominence of the scientist as the technocrat in the formulation of policy, and finally, an emphasis on the importance of statistics for policy making.

Saha realized that his ideas were different from those of a large section of the Congress dominated by Gandhi. He was aware of the practical necessity of persuading the Congress to form a national planning committee committed to industrialization. He went in search of his Lenin. The opportunity came when Subhash Chandra Bose, his friend from Presidency College days, was elected President of the Congress. Saha was in Calcutta when the news came and went to Bose's house to congratulate him. During the course of their conversation he asked Bose what he intended to do about the problem of poverty and unemployment once the Congress came to power. Bose had no effective answer.¹ The Congress was so involved in the struggle for power that it had paid

¹I am indebted to Dr Atma Ram for this information.

little attention to the responsibilities that would go with it. Saha then showed Bose a cutting of Kailash Nath Katju's speech and wondered if Bose agreed with the group that believed that the spinning wheel and the match factory were panaceas for industrialization. It was a typical confrontation between the intellectual and the politician. The pragmatic Bose always thought of Saha as the remote intellectual. However, he eventually agreed with Saha about the necessity of confronting India's problems within the holistic framework of planned industrialization.

In an address to the Indian Science News Association in 1938 Bose remarked, 'Swaraj is no longer a dream. On the contrary, we are in sight of power. Seven of the provinces of British India are now under Congress ministries. Limited though these powers are, they have yet to handle the problem of reconstruction within their respective domains. How are we to solve the problems? We want first and foremost the aid of science in the task.' (Bose, 1938, p. 139.)

Bose felt that national reconstruction was synonymous with industrialization; that India which was in the pre-industrial stage could not escape from the industrial revolution. It could at best determine whether industrialization would be gradual, as in Britain, or a forced march as in Soviet Russia. Bose opted for the second alternative, and promised that once a national government came to power one of the first things it would do would be to appoint a national planning commission. He then proceeded to elaborate some of the desiderata of national planning. While recognizing that the world would have to be looked at as one industrial unit, he advocated autarchy as regards basic needs and requirements. He visualized a process of the nationalized development of basic industries—power supply, transport, metals production, essential chemicals, etc. He admitted that every attempt would be made to preserve cottage industries but reiterated that economic planning meant planning for heavy industrialization. As regards industrial research, he promised it would be free of governmental control and organized under the aegis of the national research council. Bose concluded by emphasizing the necessity of co-operation between the expert and the politician. 'We who are practical politicians need help from you who are scientists, in the shape of ideas. We can in turn help propagate these ideas and, when the citadel of power is finally captured, help

translate these ideas into reality. What is wanted is a far-reaching co-operation between science and politics.' (Bose, 1938, p. 140.)

In an editorial in 1938 *Science and Culture* (pp. 137–8) commended the Congress President for his unequivocal advocacy of large-scale industrialization, his emphasis on the development of basic industries, the establishment of a planning committee staffed by scientists, engineers and industrialists and also the constitution of a national research council. The editorial hoped that Bose's pronouncements would clarify perspectives and, when backed by reports from the proposed planning committee, set India free from the philosophy of the bullock cart.

Bose invited Saha to a meeting which he had convened in Delhi in 1938. Saha attended the meeting only on the second day and found that the decision to form a planning committee had already been taken. Sir Visvesvaraya had been asked to be its chairman. Saha realized that the great engineer who was also the first advocate of planning in India was the most competent person, but he felt that a planning committee needed political authority and dissuaded Visvesvaraya from accepting the chairmanship. Visvesvaraya agreed with Saha that unless the planning committee had a powerful politician at its head, its deliberations would be brushed aside as a mere academic exercise. It was at Saha's suggestion that Jawaharlal Nehru was invited to assume the chairmanship of the planning committee. The committee began work in 1938, with the economist K. T. Shah as its secretary. Twenty sub-committees were constituted and Saha was a member of the main committee, chairman of the power and fuels sub-committee, and a member of the sub-committee on river training and irrigation. An interim report of the planning committee was completed and submitted to the Congress President in 1939. But the arrest of Nehru and other nationalists brought further activities to a stop.

II

The establishment of the planning committee constituted the first major achievement of the network of scientists association with *Science and Culture*. Saha then set about concretizing the other elements of his industrial society based upon the Soviet model. One crucial constituent of planned industrialization was the promotion of scientific research on a planned basis, and a

prominent place for the scientist in the process of policy making. This element of Saha's vision deserves to be emphasized. Unlike the earlier agitators for science, Mahender Lal Sircar and P. C. Ray, who saw science as an element within a syncretic pluralistic civilization, Saha saw science itself as the basis of the new civilization. At the twenty-first session of the Indian Science Congress, Saha said 'human tragedies, national, social or civic are, as Hegel aptly remarked, due to a conflict between right and right, i.e., what is right for one group is wrong for another. Is it not possible to find an absolute standard of right, independent of time, locality and tradition?' (Saha, 1934, p. 38.) Saha saw that absolute in science and in his headier moments believed that scientists should run the world.

Economic and scientific studies show that the world has resources enough for her whole population and if there is a rational programme of production and a programme of judicious and equitable distribution nobody would suffer from hunger and privation For this purpose rivalry amongst nations should give way to co-operative construction and the politician should hand over his functions to an international board of trained scientific industrialists, economists and eugenists who will think in terms of the whole world and derive means by which more and more of the necessities of life can be got out of the earth. Production should be supervised by scientific industrialists and distribution by economists. The eugenists should devise means of assigning a fixed quota of population to each geographical unit, which it should not be allowed to exceed. It may be a dream, but it is feasible provided the educational programme of the coming generation is thoroughly revised. A new educational scheme should be devised by a world congress of the foremost thinkers like Bergson, Einstein, Russell, Smuts, Spengler and others, with the special objective of weeding out medieval passions from the minds of coming generations and for training them to a proper grip and sufficient appreciation of the beauty and power of science. (Saha, 1943, pp. 40-1.)

Saha saw the beginning of such a Saint Simonian world at least at the national level in the USSR Academy of Sciences and conceived of establishing an academy of sciences of an all-India character on similar lines.

Feeling the need for a national research council composed of and controlled by scientists which would function as the central organization for this purpose, Saha held that 'the national research council would stand to the national planning commission as the

Academy of Sciences in Russia stands to the Soviet planning commission. This national research council would deal with all aspects of science, pure and applied.' (Saha, 1940, ii, p. 571.) But his vision of a planned society, with a key role for the national research council which would co-ordinate all the various subjects of research—industrial, agricultural and medical—clashed with the exigencies of war and its immediate requirements. It was in this context that Saha disagreed with that other great innovator of planning, Visvesveraya.

Visvesveraya, who was president of the court of the Indian Institute of Science, declared in one of his speeches that if the British government made no attempt to integrate science and technology, an unofficial committee called the national committee of industrial research should be formed and supported by private funds. *A Science and Culture* (1940, i, p. 574) editorial responded to the speech by pointing out that private funding was impossible. The Department of Scientific and Industrial Research (DSIR) had a grant of £700,000 annually in Britain and the national research council disbursed funds worth \$ 700,000. State aid was absolutely essential to enable a national research council to have sufficient funds. The editorial also contended that by calling for an immediate establishment of a national council of industrial research, Visvesveraya was putting the cart before the horse. Saha's vision of industrial India was a heirarchical one. It was an industrial society based on planning which encompassed industrial research along with medical and agricultural research. The editorial argued that the national research councils elsewhere did not devote themselves purely to industrial research but were responsible for the promotion of all the sciences. It, therefore, held that to start a national council of industrial research alone was premature, as there existed no national machinery for the co-ordination of general scientific research.

In the next Section we shall examine the various attempts made by Saha and his group to establish an organization for industrial research in India. The contributions to the sociology of industrial research by the Science and Culture group can be divided into five separate analytical events. There was first an analysis of industrial research as it developed within the context of late capitalism. This was followed by a superb series of studies on the implications of industrial research for a colonized society devoted to a culture of

primary products. Third, there was a critique of the actual nature of the response leading to the conclusion that the scienticization of technology was not possible within a colonized society. Fourth, there was an attempt to reform the existing organization of industrial research, and finally, an attempt was made to work out the implications of scienticized technology for the profession itself. This focussed on resolving the relation between the categories of science and technology. A number of articles were devoted to working out the relation between pure science, applied science, development and production.

Between 1935 and 1950 the Science and Culture group behaved like a monitoring group examining every single development in the synthetics industry and its implications for primary products. The contributions to the journal included systematic studies on indigo, lac, jute, cotton, rubber, petrol and mica. With cold but horrified fascination the articles chronicled the growth of the synthetic plastics industry, and pointed out that between 1920 and 1930 the industry had grown to an enormous extent. The *British Plastic Yearbook* of 1933 listed 900 firms producing an estimated 30,000 tons at an annual value of £20,000,000. (Chowdhry, 1936, p. 129.) The growth of synthetics was not a purely capitalist phenomenon. Soviet Russia, where synthetic plastics were unknown in 1928, had established factories during the first five-year plan and production in 1935 was estimated at 176 million roubles. Projected estimates for 1938 were 675 million roubles.

The phenomenal growth of synthetic plastics, especially bakelite, was threatening to force into obsolescence another natural product on which India had a virtual monopoly—lac. Scientists like H. K. Sen warned that unless radical steps were taken, the ghastly history of indigo would be repeated all over again. They chalked out a series of strategies to save lac, and first of all drew a systematic social profile of the commodity. They emphasized the peculiar division of labour where India and Burma, which accounted for 95 per cent of world production consumed less than 3 per cent of it. The only significant use for lac was in the furniture industry, but minute amounts were also used in wooden toys, penholders and bangles. The consumption pattern abroad revealed that lac was used mainly in a consumer goods industry. The use pattern was as follows—gramophone records (40 per cent), electrical insulation (15–20 per cent), the paint and varnish

industry (15 per cent), hat stiffening (10 per cent), lacquering, etc. (10 per cent). The rise of synthetic resins had already displaced shellac in the paint, varnish and electrical industries. The record industry was the last stronghold of lac. In their analysis of synthetics, the scientists pointed out that, given the advances of theoretical chemistry, synthetics could be induced to possess sets of properties which the natural product could not attain. H. K. Sen and other scientists at the Lac Research Institute in Namkum, Ranchi tried through systematic studies of the natural product to induce into it the advantageous properties of the synthetic. The scientists also tried to find alternative uses for lac. But they realized that it was difficult to find in an agricultural India alternative uses for a commodity used mainly in a consumer industrial society. The scientists emphasized that synthetic chemistry had created a revolution as radical as the machine. Synthetics offered many advantages—cheap, standardized products, mass produced for a mass consumption society. (Sen, 1937, p. 454.)

By 1940 P. B. Sarkar, chief chemist of the Indian Jute Research Institute, was reporting that the American firm of Dupont had found a new synthetic fibre. The doomsday report deserves to be quoted in full:

The Dupont de Nemours is one of the biggest industrial concerns in the USA. An idea of how big it is may be had from the fact that in the year ending in 31 Dec. 1939 it had a net income of 93,218,664 dollars. . . . A huge sum of money had been set aside to find out a suitable textile fibre and for ten long years Dupont Chemists worked on the problem. The result is a silk like fibre they call Nylon. This reminds one of the synthesis of indigo by the German chemist Adolf von Baeyer and his co-workers who took eighteen years to finish the job; the famous German firm—Badische Anilin and Soda Fabrik—spent £2,000,000 on chemical research and technical development before synthetic indigo was placed in the market. We all know what it meant for the world's biggest natural indigo trade. Who knows what will happen to the natural silk industry . . . in the coming few years. (Sarkar, 1940, p. 406.)

Sarkar also indicated the massive funds that the multinationals had committed to making nylon commercially viable. The article also reported that several multinationals had responded immediately to the development. ICI in Britain had licensed out the process. IG Farben was moving in the same direction. He added, 'the nylon issue was being systematically discussed in the Japanese parliament and the Japanese government had already issued a

subsidy for finding out a nylon like product.' (Sarkar, 1940, p. 409.) What impressed Sarkar was the political decisiveness behind every move to scienticize technology. Both governments and corporations realized that the only alternative was obsolescence.

By 1938 natural rubber was being threatened. The Russians had come up with Butadiene, the Americans with Neoprene. The developments in synthetics and consequent danger to primary products led Saha and Ghosh to convene a seminar on the chemistry of natural products. Writing at that time, Kanailal Roy warned that industrial research was bringing about a new division of labour, between the scientifically advanced and the scientifically backward countries. The latter were the chief exporters of raw materials at nominal prices and the consumers of finished articles at exorbitant rates. (Ray, 1937, p. 167.) Roy warned that the exploitation through industrial research was of the most devious kind, 'bloodless but insidious, it can be stopped only by a conscious adoption of a scientific way of life.' (Roy, 1937, p. 167.)

Complementing their analysis of the future of a primary products society, the Science and Culture group began emphasizing the necessity of a clear-cut statement on scientific and industrial policy and the role of industrial research within it.

III

In the nineteen-thirties, industry was a transferred subject in India and thus, as far as British government was concerned, a problem for the provincial governments. Most provincial governments had constituted departments of industry to which were attached small laboratories that investigated certain problems concerning industry. It was, however, felt that these laboratories suffered from a lack of co-ordination and this issue was raised at the Imperial Conference of Industries in 1926. A representation was made by the provincial governments about the necessity for co-ordinating industrial research and establishing an imperial council of industries and scientific research on the lines of the Imperial Council of Agricultural Research. The issue was initially shelved on grounds of financial stringency, but the matter was raised again in the conference of 1933, where the delegates unanimously accepted the necessity of a central agency for the collection of industrial intelligence and the co-ordination of industrial research. The

resolution proposed that this agency be attached to the department of stores and consequently the Chief Controller of Stores outlined a scheme for the proposed unit. The proposal was accepted at the sixth conference and the government sanctioned the establishment of an Industrial Intelligence and Research Bureau in 1935 with a budget of Rs 3 lakhs spread over three years. (Broide, 1935, p. 139.)

This organization was composed of three interlocking parts. There was an advisory council, composed of directors of industries and nominees of the central and provincial governments, which was responsible for policy. The administrative wing of the council was the bureau and there was a research wing headed by a scientific officer aided by eight technical assistants. The laboratory was located at the Government Test House at Alipore, Calcutta and its initial investigations dealt with a survey of the glass industry, problems of standardization and researches on cement, oils and dry cells. (Broide, 1935, p. 139.)

Meghnad Saha was extremely critical of the Industrial Intelligence and Research Bureau. He emphasized the necessity of having a more rational conception of industrial research both in terms of overall organization—finance, career systems, etc.—and in terms of the choice of research problems. He pointed out that the scales of pay recommended by the Industrial Commission of 1916 were in the range Rs 450-50-1500. In comparison to this, the salary scale of the Industrial Research Bureau was too meagre and excellence could not be expected from such poorly paid workers, no matter how capable they might be. He advised that the Bureau adopt a career structure patterned on the lines of NPL, Teddington where, while there were several grades of workers between the highest and the lowest, the salary differentials were 1:5 rather than 1:15 as in the Bureau of Industrial Intelligence and Research. (Saha, 1938, iii, p. 153.) Saha also emphasized that the Bureau was too small a body, both in terms of administrative size and finance, and recommended something more comprehensive on the lines of the DSIR in Britain.

The first steps toward reform were taken in 1936. Saha visited Britain that year and met Ernest Rutherford at the Cavendish Laboratory in Cambridge. Rutherford had just received an invitation to preside over the joint meeting of the silver jubilee session of the Indian Science Congress and the British Association

for the Advancement of Science. The great scientist was reluctant to accept the offer to speak on so historic and occasion for he felt that he lacked a sufficient acquaintance with the problems of Indian science. The two scientists talked for over an hour, during which time Saha traced the development of Indian science and Rutherford took notes. Saha found later that a considerable portion of Rutherford's speech was devoted to the topics they had discussed.

Ernest Rutherford died before he could visit India. His posthumous speech, read at the Indian Science Congress by James Jeans, was a succinct plea for a greater encouragement of science in India by the state. He added that if India was to raise the quality of her life or even the quality of her products in the market, she must make a systematic use of science. Rutherford held, unlike Saha, that priority must go to agriculture. However, he devoted a significant section of his address to the importance of industrial research. After tracing the contributions of various laboratories in Britain, Rutherford suggested that research in India must orient itself to industry. In this context he laid out certain principles of industrial research. He emphasized that it was essential for efficiency of research in industry that it be on national rather than on provincial lines. 'The establishment of similar research institutions in the various provinces cannot but lead to overlapping of work and waste of time and money.' (Rutherford, 1938, p. 364.) Rutherford also maintained that while the costs of research may be borne by the government, the planning of research must rest with distinguished men from pure science and industry rather than with bureaucrats. (Rutherford, 1938, p. 369.)

Following close on Rutherford's speech, a series of *Science and Culture* editorials and speeches at the National Institute of Sciences developed a critique of the state's neglect of science. Scientists pointed out that while during the great depression research budgets were the last to be touched elsewhere, in India, research departments were the first to suffer and suffer grievously. The Geological Survey of India lost a third of its strength due to retrenchment. The Geodetic and Trigonometric Survey lost half of its strength and the Zoological Survey fared likewise. The government made no attempt to expand research institutes. The Pope Committee which evaluated the Indian Institute of Science had recommended eight new departments at the cost of Rs 25

lakhs, but no attempt had been made to implement, the decision. In fact, the annual budget remained stationary during 1930-9. The government went even a step further by insisting that research institutions be self-supporting. The Inchcape Committee recommended that the Imperial Research Institute at Mukhteswar finance itself through the sale of vaccines. (Ghosh, 1943, p. 139.)

The editorials, however, emphasized that it was not the government alone that was indifferent to science but also the Indian entrepreneur. Shanti Swarup Bhatnagar, head of the university chemical laboratories at Punjab, held that industrialists in India had not realized the importance of science (Bhatnagar, 1938, p. 344). The inklings of recognition were there in the activities of the Tatas, Birlas and Lala Shriram, but he maintained that it was incommensurate with the situation. As an outstanding example of industry's indifference to science, Bhatnagar cited the sugar industry. He pointed out that the success of the sugar industry depended upon the utilization of its by-products and no Indian manufacturer had seriously considered the utilization of such important by-products as molasses or bagasse. Bhatnagar warned that the protection of the sugar industry could disappear or science could revolutionize technique to the extent where even this protection would be of no avail. At such a time the only thing that would save the manufacturer would be the subsidiary industries which he had developed. Bhatnagar advised the manufacturers to plan for such a situation by devoting a part of their incomes to researches on the utilization of by-products and on the improvement of sugarcane. He added that the sugar industry's practice of laying off technical staff during the off season and employing them when crushing began reduced them to the level of seasonal or daily-wage employees. The scientist pleaded that if industries were too small to maintain research institutions of their own they should utilize the services of university laboratories by sponsoring research. The ideal example of this was in Bhatnagar's own laboratory, where Messers Steel Brothers, who were interested in the problem of oil extraction, had given him a grant of Rs 1 lakh. A *Science and Culture* editorial commended this example of reciprocity between university and industry and commented, 'we are not aware of any other Indian firm that has so far come to the aid of any Indian university by giving grants from its funds, though many are in a position to do so'.

By 1938, with World War II around the corner, the advocacy of an industrial policy encompassing industrial research became much more strident. In a speech at the National Institute of Sciences in 1938, Saha campaigned eloquently for a clear cut policy of industrial development. He remarked, 'we are being constantly told by the central government that India's problems can be solved by improvements in agriculture. While the Congress raised the slogan of rural improvement, the Government of India founded the Imperial Council of Agricultural Research, but has not yet shown any enthusiasm for the establishment of a National Council composed of eminent scientific men which will include a national council of industrial research as one of its constituent bodies'. (Saha, 1938, ii, p. 3.)

Saha then elaborated a scenario: 'Let us assume in the course of the next few years that this attitude changes, that both government and political parties are agreed that the solution to India's problems lies in large-scale industrialization. It will be similar to the tasks which confronted Russia in 1918 The government will have to look to Indian men of science for advice and guidance, just as Lenin looked to the Russian Academy of Sciences when he decided to give effect to the various five years plans. Will Indian men of science be able to rise to the occasion?' (Saha, 1938, ii, p. 3.)

Saha observed that 'thanks to the retrograde policies of the government of India . . . the first class man of Indian science had no opportunity of being acquainted with any industrial problem. When therefore scientific men are confronted with such a task they will be all at sea'. Saha warned that the scarcities of material during the coming World War would be worse than in the previous War and predicted

the government will then ask the professors of physics, chemistry and other sciences to give them ready-made formulas for the manufacture of such goods and when they are found unable to work out the miracle, civilian anger will rise to boiling point and proclaim all Indian scientists as incompetent. Will it not be a good policy to take a warning whether for military needs or for permanent national work, to form a national research council, with a national committee for industrial research We have reasons to believe that this course will not commend itself to the Government of India, that they will merely create another department with a director and proclaim their duty done. (Saha, 1938, ii, p. 3.)

The worst suspicions of Indian scientists were confirmed when World War II broke out. A note was sent to the commerce minister, Ramaswamy Mudaliar, by department officials who suggested that the Industrial Intelligence and Research Bureau be abolished as a wartime economy move. Mudaliar refused to accept their advice. He abolished the Research Bureau and replaced it with a far more comprehensive Board of Scientific and Industrial Research contending that 'in wartime no economy can be too disastrous which starves industrial research and no expenditure too high which mobilizes the scientific talent of the country for the research and production of war materials.' (Ghosh, 1944, p. 5.) In August 1940, as a response to wartime requirements, the Board was established and placed under the department of commerce.

The communique issued on the occasion stated that the Board would co-ordinate the work of existing organizations, survey the work done by them and also recommend to the government research projects to be assigned for investigation either to the staff under the Board, or to other research institutions, including universities. The composition of the first Board was a blend of the scientific and the commercial. It consisted of Dr J. C. Ghosh, Dr Nazir Ahmad, Dr Meghnad Saha, Dr Shanti Swarup Bhatnagar, Sir H. P. Mody, Sir Syed Sultan Ahmad, Kasturbhai Lalbhai, Lala Shriram, P. F. G. Warren and N. N. Law. The communique said that the commerce minister would be the chairman of the Board and the Chief Controller of Stores, the vice-chairman. The government had appointed Shanti Swarup Bhatnagar as director, scientific and industrial research. A total sum of Rs 5 lakhs was allotted, of which one-fifth was for administrative purposes and the rest for research grants.

Science and Culture launched into an editorial critique of the communique. (Saha, 1940, iii, p. 649.) It pointed out that the communique indicated that the measures for industrial research were shortrange ones prompted by wartime exigencies. Any long-term conception would have included some reference to industrial planning or at least a specific statement regarding the policy of the government about industrialization. It compared the government to provincial men who were merely able to grasp one part of the industrial animal and remarked 'by creating a research board without taking proper steps for planning industries . . . the government was ignoring a vital part of the country's problem.'

(Saha, 1940, iii, p. 651.) Behind the scientist's vehemence was the memory of the First War, where industries created to meet wartime exigencies languished for want of encouragement. *Science and Culture* warned that the establishment of the Board would not lead to the creation of new research industries unless industrialists were assured of protection by the government in the postwar era when foreign competition returned.

A series of *Science and Culture* editorials began monitoring the activities of the Board, pointing out that it was a purely consultative body, which in matters of recruitment had to behave like any other government department. It suggested its replacement by an advisory body composed of professional scientists with the power of recommending to the government the appointment of all officers directly employed by the Board. But what it faulted above all was the conception of industrial research represented by a miniscule budget of a mere Rs 5 lakhs. It pointed out that neither the government laboratories at the Test House in Alipore nor the universities could cope with the work that industrial research demanded. What was required was the immediate expansion of the Test House laboratories into a national physical laboratory. These laboratories would organize researches which demanded far costlier equipment than a normal laboratory was expected to possess. In addition to the national physical and chemical laboratories, a series of advisory committees had to be formed to plan laboratories for every important branch of industry—fuels, radio, glass, etc.

Between 1940 and 1942 *Science and Culture* published a series of editorials contrasting the decisiveness with which the British government organized industrial research after World War I with the faltering attempts to establish the infrastructure of industrial research in India. Cataloguing the differences, Saha wrote that the basic distinction lay in the role of scientists in the process of decision making. In the British organization (DSIR) research was organized and administered by an advisory council of twelve, of whom ten were active scientists. The chairman was invariably a distinguished man like Rutherford. This advisory council planned all schemes, sanctioned grants, and supervised the working of the research associations and its decision was final. The committee of the privy council, though technically superior, never interfered with the decision of the advisory council. Saha then contrasted the

picture with that of the Indian Board. The chairman was the minister of commerce. Of the two secretaries, one was a civil servant and the other a finance officer. The Board consisted of industrialists, government officials and official scientists. The meetings were convened to suit the convenience of the commerce minister and the Board was only one of a score of bodies he had to attend to. The procedure was so complex that two meetings of the board and one meeting of the council were necessary before any decision could be arrived at. The result was that schemes sometimes took eighteen months to pass through all the bodies and by the time the person was informed that his scheme had been passed, he had probably lost interest in the subject. The editorial wondered why a distinguished Indian Scientist could not preside over deliberations of a purely technical nature. 'Is it not probably due to the inherent suspicion that such a man may lead the Board to activities which will not be agreeable to imperial interests?' (*Science and Culture*, 1942, i, p. 97.)

The *Science and Culture* group wondered 'why in constituting the BSIR, the norms and procedures of the DSIR which had worked successfully for twenty-five years had not been considered'. It also observed that in constituting this body no professional society, not even the National Institute of Sciences had been considered. 'In the framed constitution the wooden ideas of the bureaucracy have been entrenched, and the vast mass of scientists were kept in the outhouse like poor relations of a rich man.' (*Science and Culture*, 1942, i, p. 98.)

By 1942 the laboratories and the administration of the Board had been shifted to Delhi, given the imminence of the Japanese attack. The laboratories of the Board were located in the physics and chemistry departments of Delhi University and the Board was now attached to a separate council. The organization of industrial research now included a composite of four bodies: the Council of Scientific and Industrial Research (CSIR); the Board of Scientific and Industrial Research (BSIR); the Industrial Utilization Bureau; and the Directory of Raw Materials; the organization had its own *Journal of Scientific and Industrial Research (JSIR)*.

The Council was the supreme body of the organization. Constituted in 1942, it replaced the earlier government committee of officials that scrutinized the decision of the Board. The minister of commerce was ex-officio member of all four units. The Council

initiated proposals and approved of the decisions of lower bodies. The Board, which originally possessed many of the functions of the Council, was now a mere advisory body and the Industrial Utilization Bureau was established to issue directives on the utilization by industry of researches completed by the Board. There were also twenty scientific sub-committees which had to scrutinize projects in their own field.

But the *Science and Culture* group was still dissatisfied that little or no attempt had been made to establish the national laboratories or the chain of other commodity laboratories. Their scepticism regarding the future of industrial research was reinforced by the visit of the Grady Mission, an American technical committee which visited India for a few weeks in 1942 to find out how India could contribute to the war effort. What struck Indians of all shades from G. L. Mehta, president of the Indian chamber of commerce and industry, and scientists and engineers like Saha and Visvesvaraya, was the contrast in perspective. In other countries, planning for war was visualized within the context of postwar industrial reconstruction. In the USA, Canada and Australia the requirements of war material were placed with local industries. (Mehta, 1942, p. 199.) But this good fortune, as Mehta observed, did not extend to India. While steel production in Canada rose several times during the War, in India it remained stagnant. (Visvesvaraya, 1943, p. 105.) Visvesvaraya observed that the Grady committee recommended that India restrict itself to repairs rather than new construction. 'While Australia was asked to supply the requirements of the eastern group on the basis of a long-term programme of industrial development, India was to be merely content with feeding and clothing an army.' Visvesvaraya went on to remark that 'the Board of Scientific and Industrial Research established by the government to help industrial development had not resulted in the inauguration of a single industry.' (Visvesvaraya, 1942, p. 105.)

The reservations expressed by the Grady report, which was in fact suppressed, were fanned further by Churchill's message to the British Association for the Advancement of Science, where he categorically stated that the Atlantic Charter would apply only to countries suffering from German aggression and not to territories acquired by Britain in the past. This prompted P. C. Ray to write an open letter to Richard Gregory, editor of *Nature*. In it, Ray

remarked: 'We Indian scientists urge other scientists all over the world to assert that the question of the scientific reconstruction of society on the principles of freedom and justice should not be subject to geographical limitation.' (Ray, 1941, p. 286.) A *Science and Culture* editorial added that it was time India was thought of as something more than a reserve of men and raw materials.

Towards the final years of World War II a concern for planning and postwar reconstruction became prominent in Britain. The government felt it was also necessary to plan for India within a postwar colonial framework. It was in this context, that L. S. Amery, Secretary of State for India, invited A. V. Hill, nobel laureate and President of the Royal Society, to visit India and acquaint himself with the problems of Indian science. The message added that the most crucial issue that Hill had to advice on was 'the organization of scientific and industrial research as a part of the Indian postwar reconstruction plan', and its co-ordination with corresponding activities in Britain. Hill was also to facilitate co-operation between scientists in Britain and India.

Hill visited twelve Indian cities between November 1943 and April 1944 acquainting himself with the structure of scientific research in India. The principles on which the Hill report was articulated were presented in a speech at the Indian Science Congress in 1944. Hill was a liberal who believed that scientific organization must represent a balance between industrial initiative and state control. He recognized the inevitability of government support for science but emphasized the importance of a buffer between governmental support and governmental control. An ideal example was the British University Grants Commission (UGC). British universities received substantial support from the state but the UGC, composed of a group of independent scholars and scientists, assumed that state finance did not entail that the universities would lose their characteristic freedom. Hill cited another extreme instance of this in the British NPL which, though financed by the state, was controlled and guided by the Royal Society. (Hill, 1944, pp. 315-16.)

The second principle that Hill emphasized was the importance of a centralized organization of research outside the control of another government department. Scientific research was to constitute a department of its own directly under its own minister. The third norm that he emphasized was that every scientific

organization should be controlled by an advisory council which should be a source of independent scientific advice, unfettered by governmental constraint. Hill outlined two other criteria. First, that the director of any research institution should not only be an administrator but a competent scientist. This was the only way of assuring competent leadership. Finally, Hill emphasized that universities, government institutes and industry should not work in bureaucratically hermetized structures. To break what he dubbed the impenetrability of bureaucratic barriers, a continuous mobility of scientists between the three structures was required. This was the only way of assuring that scientists in each of these organizations appreciated the problems and achievements of the others. Hill believed that these principles were reflected in the structure of science in Britain and that his report on scientific organization for India was an attempt to create a similar set of institutions. (Hill, 1944, pp. 316-17.)

Hill, like Rutherford before him, emphasized the necessity of the centralization of research. Scientific research in India was to make a concerned effort to bring about national development in all its phases. This was especially crucial for India, where research was being conducted under a whole series of disparate institutions. 'A common policy of research can only be arrived at by understanding and appreciating the needs, resources, weakness and susceptibilities of all of them.' (*JSIR*, 1945, p. 382.) He insisted that scientific research can be starved under a department where there was a failure of interest, and cited the case of zoological and botanical research in India as evidence. Hill stated that 'if anything at all can be common to India as a whole, surely scientific research can be the first to claim that the common interest.' (*JSIR*, 1945, p. 382.)

The plan (Fig. 4-1) for the central organization of science visualized the establishment of six separate research boards. There was to be a medical research board, an industrial research board, an agricultural research board, a board of survey and natural resources, an engineering research board and a war research board. Each was to function under the direction of a distinguished scientist, who was not only to be the secretary and principal officer of his board but a member of each of the other boards. The director would organize and initiate research in his field on a nationwide scale. Each board would have a number of advisory

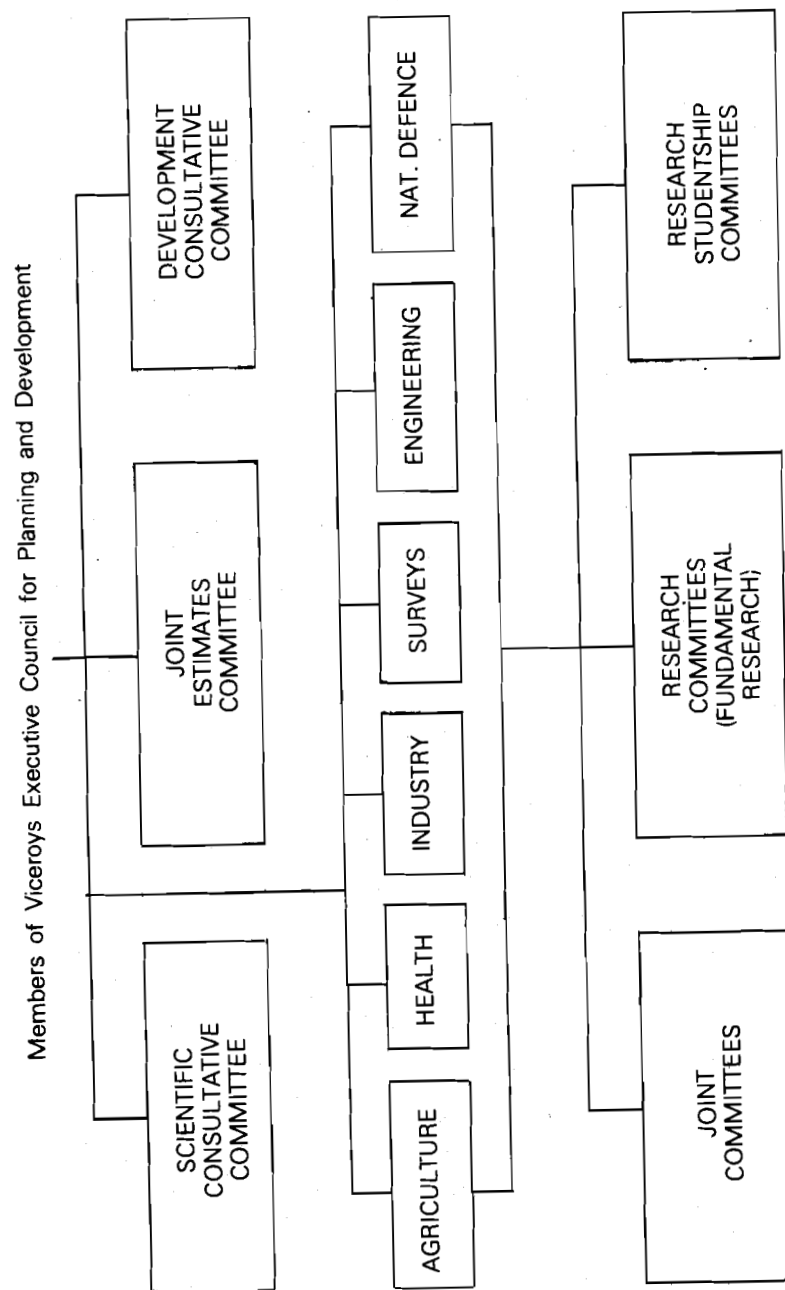


Fig. 4.1 – Hill's Scheme for the Organization of Science in India

committees to deal with various aspects of its work and would allocate grants for research in its own field to be carried out in any research institution in India. A research grants committee would be established between different boards to award grants to various laboratories to pursue fundamental research. Hill advised that if a university grants commission was established, the grants should then be administered in consultation with the latter. There would also be a joint research students' committee among the various boards to consider applications by outstanding young scientists to gain further experience abroad. Each director was responsible for preparing budget estimates of his own board. These were to be submitted to the member, planning and development. A joint estimates committee under the chairmanship of the minister would co-ordinate these estimates. Once approved each board was free to spend funds without further interference. (*Science and Culture*, 1945, ii, p. 460.)

To advise the member of planning and development, there would be a scientific consultative committee consisting of six directors and six other scientists, one from each field. Hill then proceeded to consider the relation between research and development. He emphasized the distinction between the two and believed it was a fundamental one. What Hill insisted on was the centralization of research. But development, that is, the actual application of science to practical problems, would be the responsibility of the various user departments. However, communication between the two would be facilitated through joint membership of a development or improvement council. This would ensure that the results of research were known to those who wished to apply it, and, on the other hand, those who had to do research here were made aware of practical needs. In order to assure that development as well as research was looked after, Hill suggested the establishment of a development consultative committee analogous to the scientific consultative committee. Such a body would be composed of representatives of both industry and the professions. Hill's distinction between research and development embodied in a set of organizational structures was to prove crucial in a later context.

The rationalization of scientific research under government auspices was an urgent and immediate task he claimed, for 'each year's delay gave existing interests longer time to dig in and find

better and better reasons why change should not be made' (*JSIR*, 1945, p. 383).

Two immediate consequences of the Hill report were an invitation to a distinguished group of India scientists, which included Saha, Ghosh, Mitra and Bhatnagar, to visit Allied countries and acquaint themselves with the developments of science and technology in the west; and the government decision to establish the department of planning and development.

Science and Culture responded to the establishment of the department of planning and development with a lengthy editorial locating recent moves within the context of industrial planning. There was, first, a response to the appointment of Ardeshir Dalal as member, planning and development. The editorial pointed out that his appointment was an indication of the government's rejection of the more radical efforts of the National Planning Committee and an acceptance of the Bombay Plan, which was a more modest scheme for postwar planning suggested by industrialists. The editorial remarked that the very fact that they had offered the portfolio to one of the signatories of the Bombay Plan could be taken to show, as Ardeshir Dalal had pointed out, that 'they had perhaps a certain amount of sympathy for the declared objective of the Bombay Plan, viz., the raising of the standard of living for the common man of India by a process of planned expansion of industry, agriculture, communications and other nation-building activities in so far as they are compatible with the interests of imperialism'. It warned, however, that India was in urgent need of inspiration for a national purpose and would respond only to trusted leadership, like that of Jawaharlal Nehru and others in prison. (*Science and Culture*, 1944, ii, p. 7.)

The editorial also held that, if the department were to justify the hopes it had raised, it must concretize the recommendations of the Hill report. It demanded the centralization of scientific research in a separate department under a minister. The editorial systematically indicated the anomalies in the existing structure where scientific organizations were dispersed under different departments. For example, the Geological Survey was under the department of labour and The Meteorological Department under Post and Air. It claimed that only a centralization of research would allow for a co-ordinated scientific plan. It also echoed a plea made by Hill that 1 per cent of the national income amounting to

Rs 5 or 6 crores be spent annually on scientific research. (Ghosh, 1944, p. 256.) To administer this, it advised the creation of a national research council. Its final suggestion dealt with the proposals for the establishment of a chain of industrial research laboratories, stating that their establishment should not be put in cold storage to wait till the War was over. 'Here in India, we have been talking of the NPL, NCL, fuel and metallurgical laboratories for the past three years and the talks have hardly taken us to the report stage. Nobody knows when these important laboratories will come into existence.' (*Science and Culture*, 1944, ii, p. 10)

Early in 1944, as a result of a resolution of the governing body of the CSIR, the Government of India constituted a committee under Sir Shanmugham Chetty to survey existing facilities for scientific and industrial research, and to report on the measures necessary for the co-ordination, control and direction of such research by various agencies. The committee was also asked to advise on other steps necessary for the planning of research in postwar India. Basing its information on two sets of questionnaires, one submitted to the universities and government agencies involved in research, and the other to chambers of commerce and industry, the committee submitted its report in 1945.

The committee held that industry in India was not research conscious, and research sponsored by industry was virtually unknown. The committee emphasized the crucial importance of industrial research in postwar India, both for the ordinary process of industrialization and the necessity to confront post war international competition, when scienticized technology would be the only guarantee against obsolescence. As the minimal research activity in industry was further aggravated by industry being a state subject, the committee held that the central government must take the initiative to establish a machinery for industrial research. For this purpose, the committee suggested the establishment of a central research organization called the National Research Council, to be placed under the department of planning and development. The council was to consist of sixty representatives made up of twenty scientists elected from the universities, fifteen members from scientific associations, fifteen members from industry and commerce, five members from trade unions, twenty members nominated by the Government of India, of whom not more than

eight were to be official. It advised that a block grant of Rs 6 crores be provided to enable the Council to discharge the following functions: (i) to organize and maintain national laboratories; (ii) to establish and maintain specialized research institutes; (iii) to stimulate pure and applied research in the universities by grants, and the institution of scholarships; (iv) to provide for the immediate problem of the dearth of technical and research personnel by the inauguration of scholarships in India and abroad; (v) to stimulate and encourage research activities by industry; (vi) to co-ordinate research activities of all research institutes and departments of the Government of India and to undertake the planning of research programmes on a comprehensive basis; (vii) to function as a national trust for patents; (viii) to set up a bureau of standards and specifications; (ix) to function as a clearing house; encourage deserving scientific and technical societies and foster the growth of new ones on appropriate lines. (CSIR, 1954, p. 3.)

The Chetty committee also recommended that a small executive body be created for the administration of the work of the Council.

The committee recommended the establishment of an NPL and NCL at an estimated cost of Rs 40 lakhs each. It suggested that the government establish a number of research associations to supplement those existing for jute and tea. Nine specialized research institutes were proposed: these included industrial research laboratories for food technology, metallurgy, fuel research, glass, leather and tanning, industrial fermentation and electro-chemical research. (CSIR, 1954, p. 4.)

A *Science and Cultural* editorial felt that the Chetty report on industrial research was amorphous, more a shopping list of items than an integrated picture of the forthcoming structure of industrial research in India. The most comprehensive critique of the Chetty report as a programme of institution building was written by Nasir Ahmed, Director of the Cotton Technological Laboratory in Bombay. (Ahmed, 1946, p. 455.) He pointed out that the plan was not as systematic and rational as it should be and then made a distinction between the establishment of an institution and its further development. Ahmed pointed out that one of the serious handicaps from which many research institutions suffered arose from the fact that after their enthusiastic establishment, no systematic steps were taken to assure their organic development. Many of these institutions, as a result, had been allowed to

languish and had not blossomed into fully developed research institutes. 'It is a great pity that the Industrial Research Planning Committee has practically neglected this aspect. It should be established that the mere establishment of new institutions at different points of time does not constitute a plan. A real and proper plan should in the first instance have taken into account existing institutions, which are capable of further development, and after assessing their merits and potentialities, should make recommendations for new institutions to fill the gaps that may be found as a result of the survey.' (Ahmed, 1946, p. 460.) The committee, Ahmed pointed out, had made no suggestions for the extension and improvement of existing institutions so that they may be aligned to the research requirements of the country. Ahmed then attacked the manner in which the budgeting requirements of these institutions were worked out. 'The committee has suggested that the Government of India make a block grant of six crores spread over a period of five years, and that after the initial five years the government would give an annual grant of one crore and in addition industry would be made to bear an equal burden which must be raised by statutory cesses.' The critique pointed out that these estimates had not been arrived at by systematically taking into account the specific requirements of the various research institutions that existed and those planned. The estimate was a rough and ready assessment and a detailed study would reveal that the budget requirements would be considerably larger. Ahmed hoped that these rough estimates would not stand in the way of readjustment when actual requirements were known. In this context he also added that industrial research planning was a highly specialized affair and wondered 'how a committee composed of 50 members can undertake to organize, direct and control effectively, scientific research in all its fields.' (Ahmed, 1946, p. 459.)

On April 1948 Jawaharlal Nehru passed an industrial policy resolution in Parliament and a proposal for the establishment of a planning commission was announced. On 4 January 1947 the foundation stone for the National Physical Laboratory was laid in Delhi. On 6 April 1947 the foundation stone for the National Chemical Laboratory was laid in Poona.

In our analysis of the debates on industrial research, we have shown how these debates were about the very directions in which

Indian society should move. The vision of industrial research was integral to the vision of a planned industrial society influenced by the Soviet model. We have also emphasized that industrial research grew within a particular nexus of university, industry and state. One problem remains—the conception of industrial research as a system in itself.

In analysing the subsystem of industrial research, the Science and Culture group seems to have implicitly realized that the conception of industrial research involved an understanding of the relations between the university and industry, and of the industrial research laboratory as a possible hybrid between the two systems. This involved, in turn, an attempt to analyse the relations between the categories of scientific research—pure science, applied science and between research and development. Unlike systematic attempts to work out the dynamics of flood control through the Damodar Valley Corporation, or the policy making functions of the National Research Council, the attempts to visualize industrial research as a coherent system were amorphous. Instead of a coherent system of relationships expressing the translation of a scientific concept into a technological product, one finds a set of disjunctions between applied science and pure science, between research and development. One witnesses an attempt to struggle with these categories which eventually result either in an affirmation of their separation or banal statements about their integral unity.

In the earlier articles in *Science and Culture*, the preoccupation seems to have been with the relations between pure science and applied science, the basic purpose being to preserve the domain of pure science from strains towards immediate relevance as expressed in applied science. In his writings on this controversy Saha cited as his model the British DSIR. Saha believed that the unfortunate controversy had arisen in Indian organizations owing to the influx into important research bodies of industrialists and officials. These individuals, Saha believed, had no appreciation of science. In his editorial 'Pure versus Applied Science' (Saha, 1943.) he began by pointing out that the same pressures had arisen in the early years of the DSIR, where at one time the claims of pure science were in danger of being swamped by those of applied research. Saha recounts that the danger was so great that the Royal Society was compelled to send a deputation led by the great physicist, Sir

J. J. Thompson, to the Lord President of the Council, the Earl of Balfour. Thompson pleaded the case for pure research in the now often quoted words: 'Pure science is the seed of applied science and to neglect pure science in a thing of this kind would be like spending a very large amount on the manuring and ploughing of the land and then omit the sowing of any seed.' (Saha, 1943, p. 392.)

The Council appreciated this analogy and the Lord President in the first report of the DSIR said: 'We accept the analogy and we trust that the absence of extended reference to pure science, in this report, will not be taken as indicating our lack of appreciation of its importance.' (Saha, 1943, p. 392.) Saha testified that the DSIR had financed research schemes in various branches of atomic physics, nuclear physics, the investigation of the ionosphere, vitamin studies, photochemicals, organic synthesis and even pure mathematics.

In working out the relation between pure science and applied science, Saha cited a speech by Thompson where he defends pure science on purely utilitarian grounds. Thompson emphasized that it was not the most important aspect of the question but the one that would appeal most forcibly to the politician:

By research in pure science, I mean research made without any idea of application to industrial matters but solely with a view to extending our knowledge of the laws of nature. An outstanding example of this was the X-ray whose benefit has been incalculable. Now how was this method discovered? It was not the result of research in applied science starting to find an improved method of locating bullet wounds. This might have led to improved probes but we cannot imagine it leading to the discovery of X-rays. No, this method was due to an investigation in pure science, made with the object of discovering what is the nature of electricity. The experiment which led to this discovery was remote from humanistic interest, to use a much misappropriated term. (*Science and Culture* 1944, i, p. 531.)

Thompson believed that the example illustrated the effects that may be produced by research in pure science and applied science. 'A research on the lines of applied science would have doubtless led to the improvement and development of old methods, but the research in pure science has given us an entirely new and much more powerful method. In fact, research in pure science leads to revolutions, and revolutions, whether political or industrial are

profitable things, if you are on the right side.' (*Science and Culture*, 1944, i, p. 531.)

The writings of the Science and Culture group on this controversy always became paeans to pure science. The basic dictum was Thompson's claim that pure science leads to revolutions and applied science to reform. But these essays devoted little space to the problem involved in translating a science into technology.

In 1940 at a speech at the Indian Institute of Science Visvesvaraya held that applied science should be given priority over pure science and problems chosen should be industrial in character. A *Science and Culture* editorial responded by contending that Visvesvaraya was over-emphasizing applied and underplaying pure research. Quoting R. N. Chopra's presidential address to the National Institute of Science, it contended, 'pure scientific research is as essential as that specifically devoted to the attainment of any industrial object. While industrial research is confined especially to investigations that have a direct bearing on the country, it would be a truism to add that the discoveries made in the domain of pure science may and often find application in industries at a later date and its industrial application, though its precise form cannot be foreseen at that time, has come to be an expected incident in the afterlife of a discovery'. (Chopra, 1940, p. 29.)

The ethnographic persistence with which they described achievements in pure science ceased when it came to the question of translating science into technology. After creating a disjunction between applied science and pure science, the Science and Culture group posited a disjunction between research and development. J. C. Ghosh held that scientists should not even be bothered with the latter. The task should be assigned to a national research development corporation. (Ghosh, 1944, p. 7). This distinction was further affirmed in the organization of scientific research outlined in the Hill report. Scientific research organizations were to be no longer under specific user departments. All science research was to be centralized under one structure but the development of scientific research, that is, its application to practical problems was to be left to user departments. *Science and Culture* affirmed Hill's distinction between research and development. The editorial observed 'it is not realized in this country that research cannot be tied too directly to the solution of immediate

practical problems. When the National Institute for Medical Research was started in 1914, with Walter Fletcher as the Secretary, there was a proposal to put it under the ministry of health, but Fletcher opposed the idea and had his own way; and it was placed under the Medical Research Council. . . . Nobody now doubts the wisdom of the new step. The same practice is now followed by other organizations. Nobody would think of putting the NPL under the Board of Trade, the Geological Survey under the ministry of fuel and power, or the Building Research Station under the department of town and country planning.' (*Science and Culture*, 1944, ii, p. 9.) *Science and Culture* supported Hill's thesis for the centralization of research, leaving the various user departments to make their own arrangements in applying the results of research to the practical problems they had to face.

But there were problems in creating such a series of disjunctions between research and development as in the British model that India was to adopt. After his visit to England and America as a member of a scientific mission invited by Hill, Shanti Swarup Bhatnagar remarked: 'there is one shortcoming in British organizations which one irresistibly notices'. He observed that large-scale processing always lagged behind pure scientific work. Bhatnagar pointed out that while important discoveries like penicillin, polyethylene, radar, etc. originated in Britain, they had to go to America for production on a bigger scale. The United States had achieved a high degree of co-operation between science and industry so essential for translating fundamental discoveries into commercially feasible processes. Bhatnagar cited the case of penicillin as an example of this phenomenon. Discovered by two Englishmen, Fleming and Florey, it was eventually developed extensively as a commercial process in America. Bhatnagar warned that 'unless this takes place here it will not be possible to make any real progress in industrial development because howsoever good an invention may be, the public gets interested in it only when it finds it applies to things which they know are useful.' (Bhatnagar, 1945, p. 116.)

CHAPTER 5 INVENTION

I

The roots of the National Physical Laboratory can be traced back to the war years of 1940-1, when Shanti Swarup Bhatnagar, till then Director of the Chemical Laboratories of Punjab University, assumed the directorship of the Board of Scientific and Industrial Research. The BSIR had taken over the entire staff and equipment of its predecessor, the Industrial Research Bureau. But as the war proceeded, Bhatnagar found that the scientific facilities available for industrial research were completely inadequate. As Bhatnagar, himself recollected, at the opening ceremony of the NPL.

In 1941 I made known to the government that the combined physical and chemical laboratories of which I was then director was wholly inadequate for meeting the needs of the scientific developments of the new India, and I placed my recommendations before the then government for an early establishment of the NPL and the NCL. (Bhatnagar, 1947, p. 1.)

While Bhatnagar's proposal was being considered, the laboratories of the BSIR were shifted from Calcutta to Delhi, because of the threat of the impending Japanese invasion. They were housed temporarily in the physics and chemistry departments of Delhi University. The idea of establishing the twin set of national laboratories was accepted in early 1943 and, soon after, the Council of Scientific and Industrial Research approached government for a grant of Rs 1 crore, in order to establish five laboratories, the three additional ones being the metallurgical, the glass, and the fuel research laboratories. As a first step in this process the central CSIR laboratory was split into two distinct wings, under different directors. Dr Sulaiman Siddiqui, who later left India to become Director-General of the CSIR, Pakistan, was

appointed acting-director of the chemistry laboratories. Dr Lal C. Verman, who was earlier Chief Scientific Officer of the Industrial Research Bureau, was appointed acting-director of the physical wing. 'These two wings were in due course to evolve into fully-fledged laboratories and the available staff and facilities were to be absorbed into them. The planning of these laboratories was, however, entrusted to separate committees of scientists and pursued independently of the scientific staff of the CSIR laboratories'. (Verman, 1976.)

On 3 February 1943, the governing body of the CSIR approved of setting up a committee to draw up the plans of the NPL. The committee was convened under the chairmanship of Sir Ghulam Ahmad, later Governor-General of Pakistan. Its members included Dr Shanti Swarup Bhatnagar, Dr M. N. Saha, Dr K. S. Krishnan, Professor of Physics at Allahabad University, Dr Nazir Ahmad, Director of the Cotton Technological Laboratory, Bombay and G. R. Paranjpe, Principal, Royal Technological Institute, Bombay. The committee convened for the first time in Hyderabad on 3 March 1943, where Nazir Ahmad outlined a scheme for the proposed NPL. At the second meeting at Bombay from 28 to 30 May 1943, G. R. Paranjpe outlined a proposal for the Indian Standards Institution. The committee decided at this meeting that the formulation of a complete plan for the NPL required detailed work and the services of a competent physicist, to concentrate on the intricacies of laboratory planning, ranging from objectives to architecture. On Bhatnagar's recommendation, the committee decided to recruit his old student and collaborator, Dr K. N. Mathur, then Professor of Physics at Lucknow University. Mathur was appointed Assistant Director (Planning) of the proposed NPL. At the third meeting of the planning committee on 15 May 1944, the committee decided to avail of the services of a few more scientists. The new members included Dr H. J. Bhabha, Dr Wali Mohammed, Professor of Physics at Lucknow, Dr R. M. Chaudri, Professor of Physics at Aligarh University, and Dr D. M. Bose, Director of the Bose Research Institute at Calcutta. Dr N. N. Sengupta, Director of the Government Test House (GTH) at Calcutta, who was serving as a co-opted member, was also inducted into the committee. At the fourth meeting held at Hyderabad on 12 August 1944, K. N. Mathur presented a draft memorandum of 'Tentative Proposals of a NPL for India'. The

draft was widely circulated in India and abroad for comments. The memorandum was discussed at the Indian Science Congress Session at Nagpur in 1944. Meanwhile the scientific mission invited by A. V. Hill, which included three members of the planning committee of the NPL, discussed the draft proposal at an informal meeting with a group of scientists at the NPL, Teddington, on 13 November 1944. Present at the meeting were Sir Charles Darwin, Director of the NPL, Teddington, and A. V. Hill. The proposals were also sent to Lyman Briggs, former President of the National Bureau of Standards, USA, Dr Robert Millikan, President of the California Institute of Technology, and Edwin O. Condon, President of the National Bureau of Standards, USA. (NPL, 1946, pp. 23-4.)

At the fifth meeting on 24 August 1945, the committee considered a report prepared by Mathur and Sengupta on the relation between the NPL and GTH, Calcutta. At the sixth meeting, on 3 and 4 December, the committee submitted the final draft for the consideration of the Council of Scientific and Industrial Research. The chronology of meetings that led to the establishment of the NPL is virtually complete. What we shall now proceed to discuss are the various controversies involved in the process of planning. (NPL, 1946, p. 25.)

The NPL had already established itself in the eyes of Indian scientists as the most important laboratory of independent India. The first controversy began with the question of who was to be chairman of this august body. Shanti Swarup Bhatnagar was convinced that Ghulam Ahmad should be the chairman. Meghnad Saha was somehow under the impression that he was to be the chairman of the Planning Committee of the NPL. These misunderstandings were further aggravated by the question of the location of the NPL.

The committee began by examining a series of possibilities. There was, first, a suggestion that the facilities at the GTH at Calcutta constitute the nucleus of the NPL, which could be further expanded on the land available in front of it. The second suggestion was that the laboratory be established at the new sixty-six acre site, which the government had acquired adjacent to the Indian Agricultural Research Institute at Delhi. The third proposal was the NPL be built as an extension of some existing research centre at Bombay, Bangalore or Kanpur. The committee

did not entertain the third possibility for long, and the choice narrowed down to Delhi or Calcutta. The issue was discussed threadbare before the majority opted for Delhi, contending that the space available at GTH, or even the land opposite it, was insufficient to contain its vision of the NPL. The committee itemized the following considerations, detailing why it chose Delhi over Calcutta. (NPL, 1946, pp. 28–9.)

(i) Delhi was centrally located within a 300–400 mile radius of a network of flourishing academic institutions like Lahore, Allahabad, Lucknow, Agra, where fundamental science research was being pursued vigorously. Simultaneously, it was adjacent to industrial and commercial centres like Kanpur, Lahore and Amritsar.

(ii) Delhi was the headquarters of the central government; the location of the NPL near the seat of government, as in the case of corresponding laboratories in London, Paris, Washington, Berlin, would 'be beneficial both to the laboratory as well as to the government, who would refer to the laboratory problems of the highest importance and seek their advice on scientific matters. It would also enable the laboratories to keep in touch with the government, thereby constantly bringing to bear upon them the evergrowing importance of science and scientific research in the problems facing the country.' (NPL, 1946, p. 29.) Implicit in this was the scientist's belief that independent India would find the scientist close to the levers of power.

The other consideration which the committee cited was the necessity of dispersing laboratories all over the country on grounds of security. The committee held that large research organizations, upon which the development and efficient working of heavy industries would depend, should be spread over the country, rather than be concentrated in a small area. The committee pointed out that three of the five industrial laboratories were to be situated in a small area in the neighbourhood of Calcutta. These included the Central Glass and Ceramics Institute located at Jadavpur, the National Metallurgical Laboratory at Jamshedpur and the Fuel Research Institute at Dhanbad. On the basis of these considerations the committee recommended the location of the laboratory at Delhi. The committee also added that this decision was approved by Sir Charles Darwin, director of the NPL, Teddington.

A *Science and Culture* editorial responded immediately to this decision. The editorial remarked that, 'if the view is accepted that the laboratory should start work as early as possible and under conditions available in the country, then the choice of Delhi, as against Calcutta, as a suitable site cannot be commended. We understand that the final choice lay between the two cities and the committee decided, though not unanimously, in favour of the former.' (*Science and Culture*, 1946, p. 642.) The editorial held that of the reasons offered, only one, the dispersal of the laboratories on grounds of security, deserved serious consideration. It argued that 'it is said that out of the five national laboratories and research stations proposed to be established by the CSIR, as many as three are situated in a small area in the neighbourhood of Calcutta, viz., the CGCRI, the FRI and the NML. From a wider point of view, it is of importance that the industries as well as national laboratories should not be concentrated together in one place'. The editorial then sarcastically retorted that 'evidently this consideration is not applicable to Delhi, which will be the headquarters of almost all the scientific departments, and of as many as possible of the laboratories including Agriculture, Public Health, Radio, Meteorology'. (*Science and Culture*, 1946, p. 642.) In its concluding remarks the editorial insisted that the NPL should be located in Calcutta. It made its claim for the future with an appeal to the past.

The development of research in physics is intimately associated with Calcutta. Since Sir J. C. Bose started his pioneering investigations with shortwave radio waves, the names of Raman, Saha, Bose, Krishnan, D. M. Bose, S. K. Mitra are associated with the development of applied, pure and theoretical physics in Calcutta. A large volume of experience with methods of adapting experimental techniques to semi-tropical conditions are available here. With the laboratory workshop and the library facilities available at the GTH, the Mathematical Instruments' Department, the Engineering Colleges of Jadavpur, Sibpur, the Hydraulics Research Laboratory, the Department of Pure and Applied Physics of the University College of Science, and elsewhere, it would not have been difficult to find temporary accommodation as well as many of the appliances and apparatus required for the immediate starting of the laboratory. Calcutta and its surrounding hinterland would provide a large reservoir of trained scientific workers and skilled technicians from which the personnel of the laboratory could be recruited.'

The editorial also added that the seat of bureaucracy was not always conducive to innovation in science. But behind the formal arguments of the editorial, there lay an implicit fear that Calcutta was slowly being displaced as the power centre of Indian science. This seemed to be attested by the very fact that the biggest physics laboratory of independent India was to be located away from it. Meghnad Saha soon resigned from the Planning Committee of the NPL, and as the draft memorandum succinctly commented in a footnote on its first page, Dr D. M. Bose did not attend a single meeting.' (NPL, 1946, p. 1.)

The fourth meeting of the planning committee was marred by an undertone of unpleasantness as to the qualifications of the Director. Dr K. N. Mathur, under the direction of Bhatnagar, wrote a script that only one man, Dr K. S. Krishnan, could play. The qualifications specified for the Director were, as Mathur himself admitted later, tailor-made for Krishnan. Nazir Ahmad objected to this act of pre-emption and complained to Sir Ghulam Ahmad, chairman of the committee. Dr K. N. Mathur was requested by the chairman to stay back after the formal meetings, where a new set of qualifications for the director were virtually dictated by Nazir Ahmad (interview with K. N. Mathur, 1978). Mathur complied with the request of the chairman. However, the presiding genius of the CSIR, Shanti Swarup Bhatnagar, had no doubts that the nation's most heralded laboratory should have as its director a man who was among the nation's most distinguished scientists, a man whom Bhatnagar regarded as Raman's virtual collaborator in the Nobel Prize winning discovery—K. S. Krishnan.

The last major issue related to the size of the NPL. At the informal meeting held to discuss the proposed Indian NPL (which was virtually modelled on the NPL, Teddington) Sir Charles Darwin observed that while the total number of scientists in the NPL, Teddington was 350, the number in the NPL, Delhi was 98. It was in this context that he asked the Indian delegation whether 'India would be better advised to start with a small number of fully equipped sections or with a large number of poorly equipped sections.' (NPL, 1946, p. 74.) The Indian scientists replied that a large number of sections had to be started so as to obviate jealousies of different trade and commercial interests. They eventually resolved to create skeletons of each section, but

decided that research work would initially be started only in one or two sections.

The second part of the draft document discussed the objectives of the NPL. Before one can state the objectives of a laboratory, there must be an attempt to capture the vision of the laboratory, as this may not be evident in a bald formal statement of the functions of an organization. This is particularly essential for an organization like the NPL, which was regarded, along with the Tungabhadra dam and the Tata Steel Works, as representative of the dynamism of the new industrial India. The NPL was a part of that vision of India, which was articulated by leaders like Nehru who believed that 'it is science alone that can solve the problem of hunger and poverty, of insanitation and illiteracy, of vast resources running to waste, of a rich country inhabited by a starving people.'... 'The future', Nehru contended, 'belongs to those who make friends with science.' (Quoted in Atma Ram, 1966, p. 2.)

Implicit in this statement was a belief that science had a solution to offer for the problems of socio-economic development. Inherent in it was an equation that investment in science would lead to techno-economic development. The hopes of technological miracles from science were high and the scientists during the euphoria of independence sustained the illusion that investment in science automatically meant technological prosperity. This belief in the nature of science underlined the draft document of the NPL, which began with the conception of modern society as a Darwinian world of the survival of the fittest, where the political choice was between efficiency and obsolescence, an either/or, imposed by the scientification of technology. The draft document declared that 'at no time in the whole history of the human race was the biological law of the survival of the fittest of greater application than to the present-day industrial efficiency of nations.' (NPL, 1946, p. 1.) The document stated that 'it is the business of a nation's research organizations to seek to promote this efficiency in every possible way, to assist in turning to account indigenous materials and natural facilities, to improve and standardize methods and processes; so as to cheapen products and thereby improve the standard of the people, in general to be in a position to replace old lines of manufacture, to replace and replenish worn-out fashions and faded fancies, and last, though not least, to create new demands where none existed before'. (NPL, 1946, p. 2.) It was an

appreciation of this position that led leading nations of the world to create organizations for scientific-industrial research. One of the early steps taken in this direction was the establishment of Standards Laboratories in Paris (1875), Berlin (1887), London (1899) and Washington (1901).

The basic purpose for which these laboratories were established was to carry out research in order to determine physical constants accurately. The importance of these physical constants in daily life was explained lucidly in the draft document itself. 'Across the counter the housewife buys a yard of cloth or a pound of butter. Her purchases are regulated by certain standards, one of length, and the other of weight One may not understand the driving mechanism of the electricity meter or the measuring devices of a petrol pump, but it is commonly accepted that each of them is regulated by certain standards of measurement which are impersonal and remain the same from customer to customer.' (NPL, 1946, p. 2.)

Thus, one of the first functions of the laboratory was the accurate measurement of fundamental quantities, length, mass and time. Beyond these fundamental standards were a series of derived or secondary standards, such as those of voltage, resistance, current and candlepower. All these secondary standards could be derived from the three fundamental units of mass, length and time. The draft document emphasized that the realization of these standards in terms of precise theoretical definitions required sustained research, which was both difficult and costly. The draft document elaborated the NPL's responsibility for maintenance and research on standards in great detail. Besides the maintenance of standards, the document emphasized that the NPL would carry out fundamental and applied research. The committee stated that research in applied physics would be undertaken either to discover new products, processes or uses for raw materials, and to increase the efficiency of existing practices so as to lower costs. Applied research in the NPL, the document said, should be intimately connected with the survey and standardization of the country's raw materials. Referring to fundamental research, the document stated that 'while the NPL must be free to undertake any fundamental research arising out of specific problems with which it has to deal, its main work will be concentrated on applied research.' (NPL, 1946, p. 39.) It is in this

context that the document also touched upon the relations between the university and the laboratory. The document recognized that the university was the ideal domain of pure science but concluded that 'it would be as inadvisable and impracticable to try and restrict the universities to pure and long range fundamental research as NPL to technical problems alone.' (NPL, 1946, pp. 39-40.) The planners held that the scope of the work to be encompassed by the NPL and that to be undertaken at a university 'must stay somewhat vaguely defined.' The committee hoped the NPL would remain in active touch with the university, which was not only to be the recruiting ground for the staff of the NPL, but would also provide considerable assistance to it in the solution of specific problems.

The essential functions of the NPL were then broadly stated as follows (NPL, 1946, p. 27): (i) the maintenance of research on fundamental and derived standards; (ii) research on industrial standards; (iii) investigation of raw materials for industries; (iv) standardization of raw materials, processed and finished goods; (v) exploration of the practical application of the new results of fundamental research with a view to their use in industry; (vi) framing and advice on specifications; (vii) scientific and industrial testing; (viii) publications. The committee recommended that the NPL begin with the following nine divisions: (i) Weights and Measures; (ii) Applied Mechanics; (iii) Heat and Power; (iv) Optics; (v) Electricity; (vi) Electronics and Sound; (vii) Building and Housing Research; (viii) Hydraulics Research; (ix) Analytical Chemistry.

The distribution of personnel is shown in Figure 5.1 and the following table containing details of salary structure (NPL, 1946, p. 64):

Director	1	Rs 2000-100-2500
Asst. Director	8	Rs 600-25-650-35-1000-50-1200-selection posts-1200-1500
Senior Scientific Officer	13	Rs 350-25-550-30-700
Junior Scientific Officer	18	Rs 250-25-600
Scientific Assistant	56	Probation for two years on Rs 150. Rs 180-10-300

1 DIRECTOR
10 ASSISTANT DIRECTOR (AD)
13 SENIOR SCIENTIFIC OFFICER (SSO)
18 JUNIOR SCIENTIFIC OFFICER (JSO)
56 SCIENTIFIC ASSISTANT (SA)

TOTAL 98

Designation	DIVISION								
	Weight & Measures	Applied Mech. & Materials	Heat & Power	Optics	Electricity	Electronics & Sound	Building &* Housing Res.	Hydraulics* Research	Analytical Research
AD	1	1	1	1	1	2	Specialist Officer 1	Specialist Officer 1	1
SSO	2	1	1	1	3	3	1		1
JSO	2	2	2	2	3	4	2	—	1
SA	5	6	5	6	12	8	6	4	4
	10	10	9	10	19	17	10	5	7

TOTAL — 98
TOTAL TECHNICAL STAFF — 48

* The divisions of building and hydraulics research were shifted out to be replaced by a division of industrial physics.

Fig. 5.1 — Distribution of Personnel Grade-wise and Division-wise

Two specialist officers were to be invited on special terms.

The foundation stone of the NPL was laid by Jawaharlal Nehru on 4 June 1947 in the presence of a galaxy of scientists including Sir Charles Darwin, Patrick Blackett and others who had come to attend the first postwar session of the Indian Science Congress. Speaking at the foundation ceremony, Shanti Swarup Bhatnagar explained his view of 'Big Science' organizations like the NPL and the whole chain of laboratories he was to establish within the short span of eight years before his death in 1955. Bhatnagar's speech was an attempt to visualize these laboratories in relation both to the university and to industry. He observed that the organization of science, especially during World War II, had undergone tremendous changes. Contemporary science demanded not only large-scale specialized techniques well outside the scope of university work, but the expenditure of money running into millions which could only be justified if professional continuity and continuous application were guaranteed. This was not feasible in the universities, where teaching and research went hand in hand. Research work in such a context, he felt, was bound to be scrappy. Bhatnagar insisted that fundamental research was fast becoming an industry and must be planned as such. Bhatnagar's speech was a celebration of 'Big Science'. He claimed that 'those who long for the lone worker in the basement room with his wax and string and gas-blowing torch can have them. I believe that the essential spirit of the old days, the freedom of inquiry and the time for that, can be obtained even in the pressure of great new physical and organizational techniques'. (Bhatnagar, 1947, p. 6.)

Bhatnagar also explained that the national laboratories were not intended to supplant but to supplement the research work of universities.

They will undertake work of the kind that does not ordinarily fall within the scope of industries. Their approach will be from the broad national point of view, rather than from the narrow outlook of a particular industry. The laboratories will be in a better position to employ suitable talent, and try alternative approaches to problems simultaneously without being restricted by immediate financial gains. As a general rule, problems which bear on wider social and economic aspects than any individual industry could be concerned with, are of necessity subjects of state scientific research and it is in this spirit that laboratories will fulfil their functions. (Bhatnagar, 1947, p. 6.)

Bhatnagar assured the listeners that the national laboratories were aware of their responsibilities to industry. He pointed out that applied research in India was of recent origin, and that India lacked the co-operative research associations which various industries had established in Britain. He added that national laboratories would have to solve the problems of industry. He emphasized that when completed, these laboratories would cover all aspects of research in their respective fields and possess semi-processing or pilot plant facilities for determining the value of their investigations to industry. It is in this context that Bhatnagar, in his very crucial speech, raised the subject of the relations between applied and pure research.

He remarked, 'the subject of fundamental versus applied research has recently been discussed in many quarters. But research can scarcely be divided into such watertight compartments'. In words, which in a later context were to sound so facile, Bhatnagar said 'Such a division is a purely scholastic division which ignores how scientific research develops. What is fundamental today may become very much applied in a short while. In actual practice both the theoretical and practical aspects of science have progressed by an intimate interplay. An artificial separation will be theoretically unwise and practically unworkable, and if enforced will render theory and practice a petrified routine. It is by the interpenetration of thought and work that the most fruitful result emerges.' (Bhatnagar, 1947, p. 6.) Bhatnagar assured the audience that the CSIR was sensitive to this and was giving encouragement both to purely academic research as well as to the applied, utilitarian type. As instances of the first, he cited the CSIR's grants to the Tata Institute of Fundamental Research (TIFR), the Palit Research Laboratory in Calcutta, and the Bose Research Institute, and also schemes for fundamental research being conducted under the CSIR's own auspices. The importance of both fundamental and applied work had been recognized, said Bhatnagar, by the planning committee of the various national laboratories. The scope of the work of each of these laboratories could be visualized as a spectrum 'at one end of which research work of the purest academic type and of the highest quality was carried out, and at the other, technical development of processes and equipment in stages.' (Bhatnagar, 1947, p. 5.)

On 21 January 1950, the NPL was formally inaugurated at a

festive function attended by 5,000 guests. Among those present were two to three hundred masons, labourers and electricians, working to complete the building. The scientists on that occasion realized once again that the establishment of the NPL had inaugurated the age of 'Big Science' in India. K. S. Krishnan, the first director of the NPL, remarked:

It was not long ago that we used to speak of the genius in the garret not so much with the guilty sense of our neglect of values, but almost as though it was a proper atmosphere for genius to flourish in. A story is told of a great past president of the Royal Society that, when a visitor from the continent wished to see his laboratory, he requested him to be seated in his drawing room and had the laboratory brought to him in a tray. Many great scientists have grown in and lent enchantment to this tradition which has since been called with appropriateness the string and sealing-wax tradition of Faraday, the Curies, Thomson, Rutherford and Raman. But for the majority of us, the muse of science has become a little too sophisticated to be wooed under such simple surroundings. Large laboratories, liberal equipment and enthusiastic teams are the least that seem to satisfy her, the more so when science has to be applied to industry as it will be in these laboratories. (Quoted in Mathur, 1976.)

The speeches of the scientists that day were celebrations of the boom period of Indian science, an acknowledgement of gratitude to the technological gifts bestowed on them. Homi Bhabha, one of the members of the Planning Committee, recollected that it endeavoured to plan 'the laboratory on the most modern lines and to make its scope, design and equipment such that it would be among the best laboratories of its kind in the world. It is not often in human affairs that the realization of an idea exceeds the dreams of those who planned it, but I think I would be right in saying that none of the members could have realized what a magnificent laboratory it would become.' (Quoted in Mathur, 1976.)

But if the scientists were celebrating the dawn of 'Big Science', the politicians were emphasizing the responsibilities of science to industry. The bluntest statement was made by John Mathai, who flatly stated that the NPL would shoulder the major responsibility of assuring scientific quality, especially for the large number of small-scale industries that would soon come into being. In response, Dr Bhatnagar assured the politicians present that day 'that besides the nine divisions in the original plan, a tenth, a division of Industrial Physics, had been added to the NPL. The

NPL will give the stimulus to industry which in the past has been a prerogative of the subject of chemistry.' Bhatnagar added

I am glad to say here that these national institutes will not only help industry, agriculture and commerce, they will also be of direct help to the masses. I am circulating a memo to all directors and officers in charge of the national laboratories, requesting that they should organize themselves for voluntary service to better the lot of villagers in the neighbourhood by the aid of science. We have proposed to select a number of villages near the seats of laboratories and visit them in teams on Sundays and holidays, and help the villagers to improve their cottage industries, hygiene and sanitation and their general scientific knowledge. The visits from these centres will be arranged in a regular manner and we expect to raise funds for this help ourselves without going to the government. There is nothing more infectious than personal contact and we hope that this simple experiment will enable us to take science to the villages. (Bhatnagar, 1950, p. 38.)

On 21 January 1950, free India's flag flew over the nation's most heralded industrial research laboratory. Chakravarti Rajagopalachari, Governor-General of India, presided over the function, and Sardar Vallabhbhai Patel, the Deputy Prime Minister, performed the opening ceremony. The opening ceremony had a touch of magic. Since Patel had difficulty walking from the *pandal* to the front of the laboratory to cut the ribbon, it was arranged to place a wooden replica of the NPL near him. When he cut the ribbon stretched across the front of the replica, he also cut a fine wire which brought into action a portable transmitter placed near the model. The signal from the transmitter was picked by a radio receiver placed inside the laboratory building which, in turn, activated a relay that switched on four electric motors and the connecting mechanism which slowly opened the front doors of the laboratory. Watching this bit of 'magic', 'Jawaharlal Nehru was so excited that he jumped on to the table to get a better view of the opening doors.' (Mathur, 1976.)

II

In a comparative study of the organizational strategies of the Department of Atomic Energy (DAE) and the CSIR, written in 1966, Homi Bhabha criticized the recruitment policies of the CSIR. He remarked that one result of its recruitment policies was

that a number of good scientists were lured away from the universities, leaving these institutions weaker thereby. 'Thus, for example K.S. Krishnan who was professor of Physics at Allahabad University was taken as the first director of NPL. The present director was also obtained by depriving Banaras Hindu University of a talented physicist and acknowledged authority on crystals. The first two directors of the NCL were foreign scientists; the third, Venkataraman, was Mody Professor in the Department of Chemical Technology at Bombay University. The appointment of his successor would deprive the same department of yet another serious worker'. (Bhabha, 1966, p. 279.) Bhabha felt that such a process was inevitable in an underdeveloped country, since any attempt to fill senior posts in the new organization would unavoidably result in the hijacking of talent from the one institution that possessed such a cluster of talented individuals, the university. Given government policy, the inevitability also lay in the financial and organizational nature of the Indian university. Science was getting increasingly technicized. To conduct scientific researches, one needed instruments, which the university did not have. Raman in his speeches on the CSIR called these laboratories tombs for the burial of scientific instrument and for him these laboratories may have been tombs; but the instruments they possessed lured a whole generation of university scientists into the industrial research laboratory. Further, these laboratories had a broadbased organizational structure. The pyramid sloped gradually and there was more room at the top. Apart from Delhi and Calcutta, most universities had only one professorship in each department, whereas the NPL had eight assistant directors, and twelve senior scientific officers. The salaries of these assistant directors were far more than those of a professor in an Indian university. Bhabha concluded his article by remarking that it could not be disputed that one significant social cost of building the national laboratories was the weakening of the university, by depleting it of its good people, its most valuable asset. (Bhabha, 1966, p. 279.)

There was one aspect, however, that Bhabha forgot to emphasize. His was only one side of the story. He blamed the CSIR for depriving the university of its finest talent, but did not examine in detail as to what would happen when university scientists were transplanted to an industrial research laboratory

— DIRECTOR – KRISHNAN
— DEPUTY DIRECTOR – MATHUR

PREM PRAKASH	WEIGHTS & MEASURES	1
JNANANANDA	ELECTRICITY	2
PARTHASARATHY	ACOUSTICS	3
GHAJ	HEAT & POWER	4
VERMA	ANALYTICAL CHEMISTRY	5
VAIDYA	OPTICS	6
CADAMBE	APPLIED MECHANICS	7
JOGLEKAR	INDUSTRIAL PHYSICS	8
SCHOENBERG	LOW TEMPERATURE	9*
RAMAMURTHY	RADIO COMPONENTS	10*
MITRA	RADIO PROPAGATION	11*

* SECTIONS ADDED LATER

Fig. 5.2 – The Gate-keepers

geared to the production of technology. These scientists on arrival tried to create within the laboratory the academic atmosphere which they so prized, without bothering too much about results or relevance. This ideology of the university scientist led to the hegemony of the paper as the basic product of the industrial research laboratory. In the following section we shall attempt to understand why the university scientist dominated the laboratory for so long, and also examine the forces that eventually led to his decline in the nineteen-sixties. One of the best ways to approach this is through the concept of the gatekeepers (see Fig. 5.2), a small exclusive group that determined the choice of problems in the laboratory. It consisted for all practical purposes of the Director and the Assistant Directors in charge of the basic divisions of the laboratory.

Between 1950 and 1960 the scientists of the NPL began what a Director-General of the CSIR later described as 'a race for the Olympic medals of science' (interview Atma Ram, 1977). The man who set the pace was K. S. Krishnan. 'When he took over the Laboratory, Krishnan was a man who believed in science for science's sake. To him the world of the scientist was the world of the research paper. Krishnan was a basic physicist by preference and competence. He was, like Raman, a man who would rather unravel one more property of a diamond than worry about its uses.' (Interview with scientist, NPL, 1975.)

When Krishnan came to the NPL he continued the researches which he had begun at Allahabad and pursued work in thermionics. While in Allahabad in 1944 he had suggested a series of hypotheses regarding a method for determining the saturation pressure of an electron. With the help of S. C. Jain, Krishnan began experimental work which culminated in a series of four brilliant papers on thermionics, all published in the *Proceedings of the Royal Society*. Another problem which engaged Krishnan's attention was the distribution of temperature along a thin rod or wire, electrically heated *in vacuo*. In modern electrical technology, electrically heated wires found extensive use in various devices such as electric lamps, valves, cathodes, etc. The functioning and efficiency of the devices depended on the temperature. The distribution of properties along the wire were also affected by this factor. With the collaboration of S. C. Jain, Krishnan attacked the problem both theoretically and experimentally and obtained a

series of differential equations. These papers were also published in the *Proceedings of the Royal Society* and attracted considerable attention. (Krishnan, 1961, p. 343.)

Between 1950 and 1955, Dr Parthasarathy, Assistant Director of the division of acoustics, along with a group of five scientists, published over 35 papers in international journals, virtually inaugurating a new sub-field of physics, thermosonics, which dealt with the relation of sound to heat. Until the work of Parthasarathy and his group, the literature on the relation of sound and heat energies consisted of a series of qualitative observations, disjointed and incoherent. The division of acoustics inaugurated an extensive programme of work on ultrasonic absorption in liquids, resulting in the formulation of a quantitative relation between sound and heat in liquids. Parthasarathy formulated a constant, similar to the Joule's equivalent of heat. (Parthasarathy, 1959, p. 13.)

By 1951 the laboratory had also inaugurated plans to establish a new section for low temperature physics and asked UNESCO to support the project. David Schoenberg, a leading cryogenist from the Royal Mond Laboratory at Cambridge, was invited as a visiting expert. On his advice two major items of equipment, a Collins Helium cryostat and a large electromagnet were obtained from the US under the Point Four Technical Aid programme. Dr K. G. Ramanathan, who had completed a research course and spent six months in Cambridge on a research fellowship, joined Schoenberg at the NPL in 1952. Schoenberg and Ramanathan soon completed the preliminary work required to organize the section. Ramanathan's group achieved the first liquefaction of helium in India on 27 September 1952, thus setting the base for the newly growing field of cryogenics. The report of the section itself admitted that 'the problems being studied at present are of academic rather than practical interest.' (NPL, 1954, p. 33.) It argued, however, that it provided valuable scientific training in a branch hitherto not studied in India.

In 1954, the CSIR established a second review committee whose members were Professor Egerton of Imperial College of Science and Technology; Gaston Dupuoy, Director of Central National *De la Recherche Scientifique*, Paris; S. N. Bose, Khaira Professor of Physics at Calcutta University; Lala Shri Ram, the industrialist, and A. L. Mudaliar, Vice-Chancellor of Madras University. The committee commended the approach of the NPL, pointing out

that the Laboratory was fortunate to have as its first Director a man of the scientific eminence of Krishnan. It observed that 'it is particularly gratifying that certain lines of research of a fundamental kind are being pursued at the Director's own initiative. This is of great importance, for not only does such work establish the reputation of the laboratory among the scientific institutions of the world, but out of such work undreamt of applications can follow'. (CSIR, 1954, p. 6.) In this connection it referred to Krishnan's paper on the thermionic constants which had 'excited considerable interest in industrial laboratories in other lands'. (CSIR, 1954, p. 6.) The committee commended the Laboratory's work on acoustics 'which seems well designed to bring the laboratory to the forefront of the field.' (CSIR, 1954, p. 6.) It also observed that Krishnan was encouraging original work by other members of his staff and cited as an example Vaidya's work on optics. The review committee also agreed with Krishnan's approach to standardization. Krishnan believed that the NPL was not established for routine testing but only for special testing which involved research, leading to decisions about specifications. 'An NPL should set standards of accuracy for the nation, but it should not become an establishment for routine testing of all and sundry.' The committee concluded that the overall approach of the NPL was a wise one. 'The council and Director are being wise, at the outset of the laboratory's existence, to establish its reputation in the world of science. We do not consider that fundamental work should necessarily be limited to that which arises out of the applied work of the laboratory.' (CSIR, 1954, p. 6.)

The years between 1950 and 1961 were the heyday of pure science. When Krishnan was the Director, and Bhatnagar the Director-General, every VIP from JBS Haldane to Lee Kwan Yew would be brought to NPL. It was as much a must as the Kutub Minar. In those days the NPL was the cynosure of Indian science. 'Nehru, whenever he was free, used to jump into his car and drive over to the NPL, with Bhatnagar following frantically behind. There used to be a cafe outside, where we had tea. It was so informal. Krishnan, bubbling with anecdotes used to tell Nehru about his researches. Nehru used to say "that's all very well, but what have you done for the country?"' It made Krishnan feel that he must reorient himself or at least the Laboratory to industry'. (Interview, Ramamurthy, 1976.)

Even in those days of pure science there were a few uneasy questions, about the hermetized emphasis on fundamental research in most branches of the NPL. 'I remember once, John Haldane asked, "What is the use of all this to a poor country?"' People who asked such questions were taken down to the solar cooker unit, Bhatnagar's pride and brainchild.' (Interview, Ramamurthy, 1976.) The solar cooker was the NPL's first and most publicized venture into applied science and technology. Even in the early nineteen-fifties, long before the politics of oil made the government put pressure on scientists to orient themselves to this problem, the scientists made a genuine effort themselves to look for alternative sources of energy. Homi Bhabha's effort to turn India into a nuclear power was the most glamorous and sustained of them. But along with it and before it, was a search for two other sources of energy, the sun and wind. The scientists realized that, like other tropical countries, India had abundant solar energy. The number of days of clear sunshine is large compared to the dusty or cloudy days. This, combined with the hope of alleviating the general shortage of fuel, made it worthwhile to investigate the possibility of using solar energy for cooking purposes. It was Bhatnagar who first conceived of the idea of research on solar energy, communicated it to K. N. Mathur, who then asked Dr M. L. Ghai, Assistant-Director and head of the Heat and Power Division to look into the problem. M. L. Ghai, in collaboration with three other scientists in his group, completed a survey on the literature on solar heat for cooking, offering the possibility of developing simple inexpensive equipment for such a function (Interview K. N. Mathur, 1978.) Initial work was done on a hot box but it was soon found that though this device was appropriate for keeping food warm it was not very useful for cooking food. The choice eventually fell upon a direct-type solar cooker. By 1954, a prototype of such a cooker had been built. Simultaneously, work was begun on domestic solar heaters, hot-air engines for pumping water and a steam heater. The NPL's solar cooker formed the subject of a BBC science programme in 1954. A commercial model was demonstrated in Somaliland, and in a trial run 0.75 gallons of water were boiled in less than an hour from an initial temperature of 92° F, an efficiency of a mere 33 per cent. But it was a beginning. The firm of Devi Dayal commenced production, but the cooker was to die a sudden death. A scientific idea was to

remain technologically stillborn because of overpublicity and claims which were premature. It was the oversell of the scientists, further exaggerated by the politicians, that killed it.

'Bhatnagar used to literally scream from the housetops. His enthusiasm carried him away. I remember the time a foreign dignitary was visiting the NPL, he was showing him the capacitors we had made. Listening to Bhatnagar talking, one could almost see a river of a million capacitors flowing. Actually we had just made a trial sample of a hundred. It was still to receive commercial baptism.' (Interview, scientist, NPL, 1977.) The press publicized these attempts thinking they were the first of a chain of technological miracles promised by the science laboratories in the optimistic flush of freedom. The fault lay partly with the scientist, who created the myth that investment in science meant technological prosperity. It was the myth of technology as instant applied science. The links were more tenuous. The gap between a scientifically possible idea and technologically feasible one is vast. Science, as Blackett was to remark later, was no magic wand which could automatically create prosperity. In the burst of publicity that initially engulfed them, the scientists forgot a further fact, that a technically feasible product may not yet be socially acceptable.

The solar cooker had not yet been adapted to Indian conditions. Here we have an early meal and then again one at about midday. No housewife is going to keep rotating the disc all over the roof as the sun picks up in intensity. Fuel of other kinds was more convenient. The urban housewife preferred the Burshane cooker to the solar one and, at a price of Rs 80, the latter was inaccessible to the rural masses. But the cooker was quite popular in Africa where the firm of Devi Dayal did sell a few appliances. Krishnan was not too happy about the cooker. Later, when there was a backlash from press and parliament, he withdrew into his shell, and went off anything technological. Somehow he felt that the world of pure science with the paper as its basic product, and its system of peer group evaluation was a safer and sounder one. It was more predictable than consumer or press reaction. (Interview, Ramamurthy, 1975.)

The solar cooker affair put applied science back by a decade. The hegemony of the paper-producing scientist became complete.

When it began, the NPL was an unequal blend of two cultures, the culture of the university, and the culture of the factory. While the former was no doubt dominant, two small groups oriented to technology existed in the first decade of the NPL, working on

radio and carbon technology. The radio components group at the NPL was recruited straight from industry, thanks to the initiative of Bhatnagar. The nucleus of the group was formed from a Tata Radio concern, whose leader, T. V. Ramamurthy, was attempting to make the industry research conscious. As Ramamurthy remarked

Krishnan might have been a pure scientist but the one thing about him was his tolerance. He wrote to me and insisted that I come over. 'You will have all the freedom to do what you want and what you do will benefit the whole nation, and not one single industry'. I remember we had a number of discussions on this. He brought me here in 1950.... I had set up a small research group, but the response was not too hopeful. Even when I was in Bombay, I was thinking of a field with potentialities both for the present and the future, and phenomena that could be put to practical use in electronics. I was in contact with von Hipel's research group at MIT, with Imperial College, with the NPL, Teddington, with Philips Research Laboratory under Cassimeer. I found the field of ferro-electrics and ferri-magnetics bursting with potential. Many of the techniques were common to both.

When I came to the NPL I tried to find out how best the objectives of the laboratory could be met. It was not easy. To create and staff these laboratories, we robbed the universities of their finest talent. The scientists came from the university. When they arrived here, they tried to create within the laboratory the academic atmosphere they so prized. Not many people wanted to join us. They felt what I was doing was diluting science. Groups like Mathur's, Vaidya's, Ramanathan's, Parthasarathy's, the dyed-in-the-wool scientists viewed our work with contempt. D. S. Kothari in the executive council was the most vehement of them all. He was opposed to any act which was technology oriented. He always believed that the scientists should not worry about results or relevance. He advocated science for science's sake irrespective of social importance; the more abstract the better, that has been his attitude right through. I remember when we arrived here Krishnan wanted us to work on carbon dating. That was high physics, but it did not interest us.

Resident in Krishnan's attitude to science was his belief in science as speculation, science as play, an attitude embodied best in his former colleague, Raman. The scientist was *Homo Ludens* man, the player. The concept of play was first coined by the Dutch-historian, Joahan Huizinga (Huizinga, 1955). Huizinga developed it to transcend the old categories of work and leisure, the serious and the non-serious. Play is a voluntary activity existing outside

the scope of everyday life, proceeding within fixed limits, yielding no material gain. Play is not anarchy but order. The concept fits the attitudes of pure science well. The playground was the paradigm, the problem sets of physics. Science was a search for order, and since order is a thing of beauty we have the affinity of play for aesthetics. Order within the playground or paradigm contains all the elements of beauty such as tension, poise, balance, contrast. Rules become important in such a concept of play, and deviations, such as a search for utility, threaten the very existence of the 'play community'. It is this concept of play that made Raman cry out that he would rather learn one more property of a diamond than worry about its productivity. It was this sense of play that made Rutherford proudly maintain that his work on the atom was useless. Their search was for order and beauty, not utility. 'Krishnan was not perturbed if the scientific investigation had no use at all. All that mattered to him was that it be first rate, for then, like virtue or beauty, it would have its own reward.' (Singh, 1966, p. 91.) Krishnan tried to preserve this element of play in the NPL. The tragedy lay in the fact that he chose to do so in an industrial research laboratory.

Vaidya, Parthasarathy, these scientists felt out of place in applied work, especially the kind one had to do in a developing country. When they browsed through scientific journals, they saw papers at the very frontiers of science. They were fascinated by the new theories and ideas floating around. They felt that one was not a scientist unless one was engaged in something similar. Any contribution to technology, they felt, would put them out of the science race. I remember Parthasarathy at that time was working on thermosonics. He did a wonderful piece of research which was later published in *Nature*. I tried to interest him in many of the applied aspects of the phenomenon; its present applications in electronics, in medicine, in the treatment of tumours which could not be reached by infra red therapy or diathermy.

It was this ideology of pure science that made NPL go wrong from the start. Remember it was primarily meant for a different set of problems. We tried to set patterns, without bothering to find out whether the nucleus we had recruited had a penchant for industrial research or even an enthusiasm for it. Most of them were academics and CSIR was meant for industrial problems. Many of them found themselves at sea and clung to their theoretical problems. (Interview, Ramamurthy, 1976.)

The CSIR was not meant for the esoteric research that the scientists seemed to be most inspired by. Krishnan was very enthusiastic when we

began research on ferro-electrics and even published a few papers on it. But when we started work on capacitors, every capacitor was imported. I pointed out we could replace many of these. Merely publishing papers did not interest me. I suggested we make 1000 capacitors and see user reaction. After all, the user was the final judge. Krishnan was a bit hesitant. He said 'Do you think we should do it? What if industry is not interested?' It took me three years to convince him. Luckily I had Bhatnagar's backing. I set up a small plant in 1953 which made 1500 capacitors a day and sent them to the user. Then we decided to undertake larger production. Again Krishnan was reluctant, but eventually agreed. Krishnan felt that the NPL was devoted to science and not to production efforts. In fact pilot plants were funded separately from the CSIR.

In the CSIR, right from the start there was a directive that in any laboratory, development should be carried on to the pilot plant scale. We planned to do two things at that time: 1) develop a process; 2) set up a pilot plant for it. There was great opposition to it. The scientists told me you are soiling your hands. Some called it cookery work. But cooking has its own charms in turning a recipe into an acceptable dish. I remember what Kothari told me, 'You are turning NPL into a factory, a *karkhana*.' (Interview, Ramamurthy, 1978.)

A scientist at the NPL commented: 'Yes, the scientist was right when he called the pilot plant we had built a factory. In fact, by 1965 we were employing 300 people. We were factory people. We came from the factory determined to build a factory in the laboratory. But many of the scientists came from research institutes or universities. They tried to create a university in the laboratory. One wanted to work on flame spectra and ultrasonics, problems which they had brought with them from the universities. We wanted to produce.'

As mentioned earlier, the function of the Laboratory was the maintenance of the primary standards of mass, length and time. The reference standard possessed by the Laboratory in the early stages were certified for their accuracy by the NPL, Teddington. It was only after the enactment of the new Weights and Measures Act (1956) that it was finally decided that India would subscribe to membership of the International Bureau of Weights and Measures, Paris. This decision enabled the Laboratory to acquire at a nominal cost the standard kilogramme and meter which were certified by the Bureau of Standards in Paris. The passing of the Weights and Measures Act and the introduction of the metric system were important events. Although the basic responsibility

lay with the Indian Standards Institution under Dr Lal C. Verman, the NPL was closely associated with the Standing Metric Committee of Commerce and Industry both during the drafting and the implementation of the Act. (NPL, 1962, p. 4.)

In the early days of the metric era, neither the manufacturers nor the public were familiar with the shape and denomination of the new weights. The division of weights and measures made 20 sets of commercial, grade-cast iron weights, ranging from 50 kgs to 100 gms for display all over the country. This proved very helpful in popularizing metric weights. (NPL, 1962, p. 4.) Under the terms of the new Weights and Measures Act, all the states and union territories of India were required to set up weight and measurement enforcement agencies. The enforcement department had to be provided with the necessary testing equipment including a number of balances ranging from 2 gms to 50 kgs. The cost of importing them was Rs 10,000. The immediate foreign exchange requirement of the enforcement department came to Rs 1 crore. In order to avoid such a huge expenditure in foreign exchange, steps were taken to improve the quality of the balances. As a result of advice from the NPL, a flourishing industry for precision balances was established. (NPL, 1962, p. 5.)

While K. N. Mathur and the weights and measures group were collaborating with the Indian Standards Institute (ISI), Krishnan was asserting himself again in the realms of international science. The year 1957-8 was International Geophysical Year (IGY). As early as 1952, the International Council of Scientific Unions (ICSU) had convened a special committee to prepare for IGY. Krishnan was vice-president of ICSU and chairman of the Indian Committee for IGY. He began participating enthusiastically in the range of IGY programmes which covered 13 main fields of science and involved scientists from 70 countries. The Radio Propagation Unit constituted in 1956 at the NPL became the headquarters for most of this activity. The IGY helped the new department of radio astronomy under Ashish Mitra to move to the forefront of a growing discipline. It was in the international character of the IGY rather than in the political intricacies of indigenous technology that Krishnan found his metier. As K. R. Ramanathan put it,

The greatest single achievement in organized science in history was perhaps the building of the first atom bomb. It required the bringing

together of many top ranking scientists, technologists and organizers on an unprecedented scale. But they were top ranking men of a few countries only. The IGY in my view was an undertaking of greater magnitude and difficulty. It involved the bringing together of scientists of many nations, many ideologies and varying stages of scientific development. A keen, diligent observer with modest education in any corner of the world had a respected place in the IGY scheme. The approach is human and earthy and the potentialities for the unification of mankind greater. (Quoted in Chapman, 1958, p. iii.)

The production of technology on the other hand was a more problematic affair, as the scientists were soon to realize.

The next significant move toward the creation of technology came from the Industrial Physics Group in 1959. This group, which had been attached as an afterthought to the NPL in 1950, was basically devoted to the research and development of an indigenous carbon technology. The leading scientist of the group, Joglekar, was a part of the BSIR research group and had initiated exploration in carbon technology under Bhatnagar and Verman. With the establishment of an industrial physics section, J. D. Joglekar was appointed Assistant Director of the division.

Verman and I began working on carbon technology while we were with the CSIR. We first worked on dry cells. Indian manganese ores were run down during the war by British geologists. I remember the British geologist Brown remarking that Indian manganese was no good as it had a lot of iron in it. We examined 23 ores and as a result of our work six Indian ores were found suitable for dry cell manufacture. We then moved to carbon rods. Bhatnagar suggested, 'Why not manufacture carbon rods?' But due to want of enough workers, space and money we did not progress much. Remember we were still in wartime Calcutta, forced to attend to more immediate problems. In 1950, after shifting to the NPL, we were in a better position to pursue our work further. We made a few thousand brushes of different grades and supplied them to various industries and government departments. All the equipment necessary was built in the laboratory. The process was released by NRDC to Beni Ltd. in 1956. After handing this over, work began on high intensity arc carbons. While work was being conducted on a pilot plant scale, the firm of R. J. Wood decided to accept our products.

The original contract was for a period of four years. But the company felt we hadn't met the full requirements of the contract and the case went for arbitration. One trouble was that NRDC made a faulty contract. All sorts of conditions were imposed on us, and the NRDC which is supposed

to mediate between the scientist and entrepreneur did not help. The firm expected a turnkey technology. Our contract was time bound, and R. J. Wood wanted a full-scale technology. They said I must have a pilot plant and NRDC insisted on it. I have been reading about it. There is no standard definition of what a pilot plant is. The definitions are different and this becomes a source of conflict. Take drugs. A product is prepared on the laboratory bench. The demand for some of them is so small that the production unit can be established in the laboratory itself. But take the case of arc carbons. What would one consider the proper scale for pilot plant production? If we were to go along with Wood's idea it would mean setting up a full fledged factory. The trouble was NRDC insisted that the contract entailed just that. That was what I resisted. Whether the laboratory has the funds, space, and manpower required has also to be seen. (Interview, Joglekar, 1975.)

The scientists of the Industrial Physics Group realized that the translation of science into technology was far more complex than they had imagined. Industrial research is no longer work on a laboratory bench. Between the invention and the innovation there is a large gap, a realm of uncertainty. It is this that the scientist has to cope with, and they understood that they required different concepts of organization for it.

An invention by itself does not constitute an innovation. It is only a small part of an overall process. I remember when I first sensed it. I got an award while at the Indian Institute of Science for the first Indian car battery. I couldn't translate it into anything commercial. How could I when Japanese batteries cost eight rupees, and Exide sold dirt cheap at twelve?

Modern technology, both in its inventive and innovative aspects is becoming extremely complex, governed by too many extraneous factors, many of which we cannot anticipate. For example failure in one technology may be a result of drawbacks in another technology. For instance, machine-building technology in India had not developed till 1956-7, and our work suffered because of it. I think it is time we bring in systems planning like GEC are doing. The carbon project depended upon so many variables and a constant watch had to be kept on them. We had to study how far different variables like knowledge, equipment, space, raw materials affect the eventual success of the project. Nobody bothered about these things in the NPL.

I submitted a note to the director on the use of operations research (OR) in industrial research. It is gathering dust somewhere. Why OR? Because in the NPL we take on problems without going into their economic viability. Somebody gets an idea and starts working on it. This

was specially so in Krishnan's time. OR helps you pin down these variables. Every scientific organization needs an economic branch to do some preliminary work. Take any problem. How much raw material do we need? Is the end product saleable? How much equipment do we have to import? These have to be detailed clearly. (Interview, Joglekar, 1975.)

The scientist emphasized that the uncertainty was heightened by the politics of the technology. The NPL eventually released its patent on arc carbons to eight parties, each of which paid a royalty of Rs 10,000. But the NPL then discovered that the government had simultaneously issued a license to Union Carbide for 3 million arc carbons in 1961. Two years later the government increased the quota by another 3 million, when the total requirements of the country were 7 million. The firms were prepared to lose their royalty payment rather than lose lakhs afterwards.

'We always had to fight these big firms. Union Carbide had a monopoly on arc carbons. They do not like anyone to come up with indigenous know-how. They have more resources at their command than we do and they try to make use of everything to cut down prices and exert influence on government agencies like the DGT. They use their influence to get licenses, and not only that, they get themselves overlicensed. The multinationals have always been a problem.' (Interview, Joglekar, 1976). Referring to all these areas of uncertainty, Joglekar demanded that the problem of commercialization be left to some party other than the scientist.

III

K. S. Krishnan died of a heart attack in 1961. 'When Krishnan died, both pure science and the NPL lost that touch of grandeur. Questions began to be raised in public as to whether the work in the NPL was benefitting the tax payer.' (Interview, scientist, NPL, 1975). Jawaharlal Nehru, worried about the decline of the NPL, summoned P. M. S. Blackett to advise him on its future.

Blackett was one of the outstanding cosmic physicists of his time. Apart from being an undoubtedly competent scientist, Blackett was a powerful political influence, one of those British scientists who walked the corridors of power. A member of the Barlow Committee on scientific manpower, deputy chairman of the Advisory Council of Science and Technology and President of the Royal Society, Blackett belonged to that small group of

scientists whose personal links with Harold Wilson shaped the Labour government's attitude to science and technology. In addition, beyond his contributions to cosmic ray research and the development of British science, Blackett, along with Bernal, Hill and Haldane belonged to a group who contributed significantly to the development and establishment of science in the Third World.

Blackett's role as an adviser to Nehru began in 1947 when he visited India to attend the first post-war session of the Indian Science Congress. During the luncheon session he found himself seated next to Nehru, and their discussion on the problem of modernizing the Indian army led to his being invited to India a few months later, to advise on the research and development needs of the armed forces. For the next twenty years Blackett was a frequent visitor, whose advice encompassed various aspects of institution building in Indian science, such as the INSA, the TIFR, the UGC and the CSIR. Blackett was deeply concerned with the difference between what he dubbed the 100-dollar and the 1000-dollar countries, a gap which he believed could only be reduced through an intelligent application of science and technology. The Blackett Report on the NPL has to be understood in this context.

The Report raised fundamental questions rudely and brutally. 'What use is two (esoteric) papers in an international journal to a developing society? Is pure science of any use in an industrial research laboratory?' (Interview, scientist, NPL, 1976.) The Report deserves detailed consideration. Blackett reminded scientists of the NPL of something they had forgotten: the objectives of the organization. The NPL was basically established for the maintenance of standards and the commercial testing of manufactured instruments, equipment and apparatus. Most of the divisions of the NPL—of weights and measures, acoustics, heat and power, electricity, electronics, applied mechanics and optics—were established for this purpose. Blackett felt that industry in India must make the greatest possible use of the NPL to certify the accuracy of their measuring instruments and the functional reliability of their products. This kind of work, while commercially profitable, was of a routine sort and had in fact been prescribed during the first decade of the NPL. (Blackett, 1963, p. 1.) The academically oriented scientists felt that routine testing hardly carried the seeds of a research paper. Blackett realized this but emphasized that the

maintenance of standards should be kept at a practical level. 'Expensive and esoteric research work was not necessary at this stage of development.' (Blackett, 1963, p. 2.)

Unhesitating in exposing the contradictions inherent in an industrial research laboratory at the nascent stages, Blackett revealed that most of the divisions of NPL were engaged in basic research which had little or no relevance to industry. He admitted that the scientific contributions of the divisions of low temperature and solid state were of a high order, but held that they were industrially irrelevant, and emphasized that most of the pure science work at the NPL was university oriented. He observed that 'the quality of much of the research done (in the other divisions) did not impress me. I think the main reason for its weakness is that much of the work done is by junior personnel and research fellows without any adequate direction. Some of these research problems seem dull and invented mainly for the purpose of producing subjects suitable for Ph.D's'. (Blackett, 1963, p. 4.)

Realizing the academic bias of many of these divisions, Blackett recommended a drastic reorganization of the NPL and advised that all the basic scientific work be put together in one section of the building and that the section be called the centre for Theoretical Physics after its amalgamation with the university. 'The senior scientists engaged in this work should also be professors and readers in the university and all the scientific staff of the basic science groups at the NPL should effectively be university teachers with normal teaching duties of up to 16 hours or two days a week. They should lecture, demonstrate, do tutorials, and take part in the administration of the physics department as normal university staff do'. (Blackett Report, 1963, p. 5.) The University, he felt, would gain tremendously. The scientific equipment available at the NPL 'which is being inadequately used or not used at all' would be manna to the starved universities. The university would also benefit through the increase in staff which would reduce the teaching load. The amalgamation of the Centre for Theoretical Physics with Delhi University would create a strong indigenous post graduate department which, in Blackett's view, was the 'key to scientific advancement and the mundane saving of foreign exchange by reducing the number of students who have to be sent overseas for Ph.D. work.' (Blackett Report, 1963, p. 6.) It seemed to Blackett

that a large part of the NPL was literally a university organization shirking its teaching duties. The first set of recommendations sought to remedy this lapse. After the transfer of the academically oriented scientists to the Centre for Theoretical Physics, Blackett wanted the remnants of the divisions of Weights and Measures, Applied Mechanics, Heat and Power, Electricity, Electronics, and Acoustics to be amalgamated into one powerful division under a separate director, organizationally oriented to industry, and with no other responsibility. 'The total number of personnel of these above seven divisions was 104, of which twenty-four were above the JSO level.' (Blackett Report, 1963, p. 6.) He recommended that at least two-thirds of these might be transferred to the new standards and testing section.

What concerned Blackett most was the NPL's general isolation from industry. He complained that 'the testing activities of many of these units were too small in scale. In 1960-1, the division of heat and power tested only four, thermometers for outside bodies, in 1961-2 only twenty-five' (Blackett Report, 1963, p. 8). The testing activities of various other units like the applied mechanics sections were too small to have any significant impact on industry. This was due to the fact that laboratory testing had been discouraged by the first director. Blackett believed that the director of the standards division should aim at persuading the new industries of India to make the greatest possible use of the NPL to certify the accuracy of their measuring instruments, and the functional reliability of their products. 'Only when confidence has been established through the world in Indian science and technology, in the accuracy and reliability of Indian instruments, will it be possible for them to displace foreign imports to the laboratories and manufacturing plants of India, and then to break into foreign markets. By vigorous publicity and admonition, the manufacturing firms must be persuaded to send a large fraction of their output for certification to the NPL, and the potential purchaser must be persuaded that the extra costs of buying a balance, a set of weights, ammeters, gauges and capacitors, which have individual NPL certificates is worth the extra cost.' (Blackett Report, 1963, p. 1.) Blackett insisted that this division be commercially conscious.

The organization of the standards and testing division must be such as to compete with this in the most efficient way with the minimum of

manpower. Charges should be high enough to make industrialists believe in the value of the NPL certificate. The standards and testing division as a whole might well aim to cover an appreciable fraction of its cost from certification. The personnel of the division should be made cost-conscious, encouraged to develop quicker and cheaper methods of testing and should participate in a drive to get more business. Co-operation with the ISI should be close. Government action to make some type of certification compulsory might be considered.' (Blackett Report, 1963, p. 2.)

Blackett was impressed with the work of the radio components unit and its ceramic pilot plant. These two closely linked units he remarked, 'were doing first class work in getting into production a number of electronic and magnetic components. The scientific direction is good, the top personnel capable, practical and energetic. The pilot plant is really a production unit of no mean capacity.' (Blackett Report, 1963, p. 2-3.) Blackett recommended that the unit break away from the NPL into a separate manufacturing unit.

The executive council of the NPL convened a meeting on 26 February 1963 to consider the Blackett Report. The council decided to appoint a sub-committee, under the chairmanship of M. G. K. Menon, to consider the feasibility of implementing the recommendations of the Report. The sub-committee met on 14 and 15 March 1963 at the NPL; it examined the scope and functions of the NPL as originally laid down, and also the previous recommendations made by the Egerton and Ghosh Committees. The Menon Committee agreed with the spirit of Blackett's recommendations. What it tried to confront was the organizational problems involved in restructuring the NPL. It began by quoting the Ghosh Committees recommendations of 1955, that 'national laboratories should concentrate on subjects which have an applied or industrial basis', and in this context, it agreed with Blackett's contention that the major role of the NPL over the next decade should be in the field of standards and testing. It then proceeded to confront the nature of the various sections in the NPL which were to realize this objective. (Menon Report, 1963, p. 2.)

'In the NPL as constituted today there are certain divisions such as Weights and Measures, Electricity, etc, whose work is concerned entirely with the maintenance of standards and testing. On the other hand, there are the solid state physics and the low

temperature physics divisions whose work is fundamental and basic in character.' (Menon Report, 1963, p. 2.) Between the two ends of the spectrum were some other divisions whose work was mixed and included both aspects. The problem, they emphasized, was how to create an optimum mix in which both types of activities, standards and testing and fundamental research, could be strengthened and expanded. The subcommittee felt that, given the conditions, the only possible solution lay in the bifurcation of these two sets of activities. The attempt to develop them in a unified manner was not likely to benefit either in terms of substantial development and sustained growth in the future.

The Committee recommended that the activities of the NPL should be separated into two categories: (i) that part concerned with fundamental research alone, which was to be developed into an institute for research in basic sciences, the Centre for Advanced Physics; (ii) that part whose major activity had been in the field of standardization and testing. This was to be reorganized and developed and referred to as the National Physical Laboratory (reorganized), NPL (r) (Menon Report, 1963, p. 3). The Committee recommended that there should be a close relationship between the NPL (r) and Indian Standards Institutions (ISI) so that 'the knowledge and experience of the latter concerning relationships with industry could be used to the best advantage, and the scientific background and the developmental and research facilities of the former should be placed at the disposal of the standardization projects of the latter in the larger interests of the industrial development of the country.' (Menon Report, 1963, p. 3.)

The Committee then considered the two sections separately. It observed that the Solid State Physics and Low Temperature Physics divisions were engaged in fundamental research, which was generally unrelated to the other activities and divisions of the NPL. The Committee agreed with Blackett that the work carried out by these two divisions was first rate and advised that it should be strengthened and expanded substantially. It felt that fundamental research develops best in an academic atmosphere. This implies lecture programmes, colloquia, seminars and, most important, students. The Committee concurred with Blackett's recommendation that members of the two divisions should participate in and initiate teaching programmes, but pointed out

that the relationship between the proposed center and the university had to be worked out. Opposing Blackett's suggestion of a complete amalgamation with Delhi University they suggested an alternative relationship between the University and the research institute as exemplified by the Saha Institute of Nuclear Physics and the Calcutta University. This Institute was responsible for teaching a post graduate course in nuclear physics for Calcutta University. It had its own staff and director but the University was represented on its governing board.

The Committee felt that the other units of the Laboratory, viz. (1)Weights and Measures, (2) Applied Mechanics, (3) Heat and Power, (4) Optics (5) Electricity (6) Electronics, (7)Acoustics, (8) Industrial Physics, (9) the Radio Propagation Unit (RPU) unit, (10) Time and Frequency, (11) Transistor Circuits constitute the rest of NPL (r). The principal role of the NPL (r) would be in the field of standardization and testing. In addition, basic and developmental research, which is related to its major function, would be carried out to the extent necessary, as summarized in table 5.1.

TABLE 5.1

NPL		
Centre for Advanced Physics	NPL (r)	Manufacturing Units
(i) Division of Solid State Physics	(i) Weights and Measures	(i) Radio components
	(ii) Applied Mechanics	section and
	(iii) Heat and Power	ceramic
(ii) Division of Low Temperature	(iv) Electricity	plant
	(v) Acoustics	
	(vi) Electronics	
	(vii) Optics	
	(viii) RPU	

The Committee then confronted the third major section of the NPL, the manufacturing units. It agreed with Blackett that 'the radio components section and the ceramic pilot plant on the one hand and the glass technology section on the other be constituted into independent manufacturing units to be managed in the way a commercial firm is managed. They may for the time being work in their present locations with the ultimate aim of finding indepen-

dent accommodation. It is clear that the direction, organization, cost accounting and responsibility for the development of new products of such production-type units should not be the responsibility of the NPL (r).' (Menon Report, 1963, p. 7.) Following Blackett, they maintained that these units should become small firms on their own. 'By taking these out of the existing NPL, they will expand industrially in a substantial manner; if they were to do so within the NPL they would stunt the growth of other activities.' (Menon Report, 1963, p. 8.) The Committee was here raising an issue beyond the relation between applied science and pure science. It was a question of how much of the technological spectrum the laboratory should encompass. If the first tended to work out how the laboratory was different from the university, the second focussed on how the laboratory must be viewed as distinct from the factory. We shall explore the second question in greater detail later.

The Committee then ended its examination of the Blackett Report by contending that 'existing within NPL, within one organizational set-up, were many types of activities, which for their growth required different organizational structures'. (Menon Report, 1963, p. 8.) The Committee concluded that to overcome this problem, Blackett had rightly divided it into: (i) fundamental research (solid state physics and low temperature) at the Centre for Advanced Physics; (ii) Standards, testing and certification, the work of the NPL (r); (iii) Manufacturing units.

The Blackett Report, which raised the question of the relation between pure science and applied science within the context of industrial research, was subject to a second scrutiny by the Executive Council of the NPL on 29 April 1963. The basic purpose of the meeting was 'to consider the report of the sub-committee set up by the Executive Council to go into the recommendations of the Blackett Report. (NPL, 1963, p. 1.) The Executive Council professed to agree with the spirit of the Blackett Report. It observed that 'the main recommendations dealt with the separation of certain sections doing fundamental research, and their constitution into a centre for advanced physics.' (NPL, 1963, p. 1.) It is in this context that the relation between fundamental and applied research was raised again at the council meeting by S. N. Bose, D. S. Kothari and S. Bhagvantam.

Bose felt that it was beneficial to separate fundamental from

applied research. He emphasized that the management of universities and the national laboratories were different things and should be dealt with separately. Kothari thought fundamental and applied research should not be moved apart until there were compelling reasons to do so. Bhagvantam asserted that by raising the question of pure and applied science, Blackett was raising a general national question and trying to solve it within the ambit of one laboratory. Bhagvantam held that the relation of pure to applied science was a national policy issue and should therefore be considered by the third CSIR Review Committee before the relations between pure science in any one laboratory were resolved. The Director-General, Syed Hussain Zaheer, also contended that there was no intention of separating fundamental and applied research at the NPL. Zaheer claimed that the relation between pure and applied was purely an organizational problem and held that it was in the interests of both aspects of work at the NPL that they receive adequate attention. This was possible only if their separate identities were recognized. But an analytical separation need not be followed by an institutional one. (NPL, 1963, p. 2.)

The Executive Council later discussed the conceptual and institutional relations between pure and applied science and the relation between the laboratory and the university. There was unanimity regarding certain fundamental issues: (i) that it was not desirable to separate fundamental from applied research; (ii) that the universities had to be strengthened; (iii) that there was a need for collaboration between the laboratory and the university.

The members of the sub-committee, who had earlier examined the Blackett Report, clarified that they had not gone into the basic policy issues of what should be the relation between pure and applied science, or of the university and the national laboratories. They had confined themselves strictly to their terms of reference, which were 'to explore the feasibility of Blackett's recommendations.' (NPL, 1963, p. 1.) They added that 'it was desirable to place the applied and fundamental sections under two different leaders as the outlook of these two sections was different; one to be definitely industry-oriented, and the other academically-oriented.' (NPL, 1963, p. 2.) The sub-committee held that the administrative relation between the two was a matter for the Executive Council.

After a full discussion the Executive Council recommended that

'the suggestion for separating fundamental research at the NPL, unrelated to the other activities of the laboratory, and establishing a Centre for Advanced Physics, be accepted in principle' (NPL, 1963, p. 2). The Executive Council further laid down that the NPL Centre for Advanced Physics and the its centre for applied research both be provided with heads of independent status; the head of the applied section would in the first instance exercise general superintendence over the common services. The Executive Council also held that 'having accepted the principle of collaboration between the Centre for Advanced Studies and Delhi University (and also other universities) . . . the DG may work out a scheme in consultation with Delhi University with a view to giving shape to the proposal.' (NPL, 1963, p. 2.) The Executive Council added that the Radio Components unit be kept separate from the rest of the NPL as a development-cum-production unit.

The problem of the relation of pure science, applied science and technology also confronted the second Director of the NPL, P. K. Kitchlu. In a note to the Executive Council on 7 April 1964, Kitchlu remarked that 'during the last four months that I have been at the NPL I tried to understand its functions and objectives, and have carefully read for that purpose some reports, particularly the Ghosh Committee Report (1955), the Blackett Report (1963) and also the proceedings of the Executive Council.' (Kitchlu, 1964, p. 1.) Kitchlu pointed out that the NPL was established with the principal aim of helping the industrial development of the country in fields based on the application of physics. It was also to maintain standards of important physical units such as length, mass, time etc. Testing was one of its basic functions, though not a major one, particularly in view of the fact that there was already a government test house at Alipore. However, Kitchlu observed that he was surprised to find that 'the total annual volume of testing work done at the NPL has been less than Rs 50,000. It was also doubtful whether the testing work at the NPL would grow in future to an extent which would justify an annual expenditure of over Rs 40 lakhs on this activity alone.' (Kitchlu, 1964, p. 1.) He then proceeded to outline a solution which would emphasize the technological thrust of the NPL.

Kitchlu defined as one of the main functions of the NPL the scientific understanding of the physical behaviour of materials used in the construction of instruments, tools, structures, etc; and

to lay down standards for the performance of products and articles. The NPL would orient itself to objective basic research and the problem selected for investigation should have a bearing on its industrial objectives. Basic research thus was no longer merely academic. It had to be reoriented to serve the long-term goals of industry. Kitchlu then confronted the relation between pure and applied science.

He commented, 'given the peculiar conditions of India where emphasis was rightly laid on the development of small-scale industry, the NPL should be geared to offer assistance to small-scale units for guidance. There is quite a lot that can be done on the basis of existing knowledge and techniques.' (Kitchlu, 1964, p. 2.) But this function, Kitchlu emphasized, 'can be performed effectively only if the people who are expected to find the answers keep themselves in the stream in the stream of knowledge and do not become routine workers.' (Kitchlu, 1964, p. 2.) Citing a British NPL report of 1960, Kitchlu held that 'the problems of applied physics often come directly from outside inquiries, at the same time it (the organization) must undertake fundamental research to have the background from which to answer these questions.' (Kitchlu, 1964, p. 2.) Kitchlu observed that the Solid State and Low Temperature physics divisions had been separated to constitute a centre for advanced physics, a unit with a academic bias. He emphasized that if the NPL was to devote itself to research in applied physics, it would be better not to isolate these divisions from practical problems. Rather, their work should be oriented towards application. Kitchlu turned the pointer back from the academic to the industrial. The services of these divisions would be required for: (i) the understanding of the behaviour of materials; (ii) the study of their standards and performances; and (iii) developing a technology of new products.

Kitchlu contended that the bifurcation of the NPL into two parts at this time would not help the proper functioning of either the NPL or the Centre for Advanced Physics. The two wings were complementary and should sustain each other. 'All applied work needs the active support of basic understanding at all stages. Work is bound to suffer without it. Under the old system a discontinuity was posited between the two units. The work of the two units could not be correlated, as the Centre for Advanced Physics was

supposed to do academic research, unrelated to industrial needs.' (Kitchlu, 1964, p. 3.) Kitchlu realized intuitively that any division of labour presupposed hierarchy and any hierarchy would harm the functioning of an industrial research laboratory. 'To group sections oriented to theoretical research as "advanced" by comparison, can only create a sense of superiority amongst some and make others smart under a sense of inferiority. Such a tendency is already noticeable and if unchecked can create severe problems.' (Kitchlu, 1964, p. 3.)

Kitchlu was among the first senior scientists to realize that the problem of the NPL was not only one of management reorganization but a cultural one requiring a wider anthropological understanding. The problem was twofold: a conceptual one of the categories of science, demanding a particular relationship between pure science, applied science and technology, and an institutional one of creating and maintaining an organizational system suitable to the industrial research laboratory, an institution which stood halfway between the university and the factory, which while it possessed elements of both, combined them in a network of relationships different from either the university or the factory.

Kitchlu realized that the disjunction between pure science, applied science and technology had to be transcended and replaced with a more synergistic relationship between the three. He was aware that one such solution lay in the recent developments of materials science. Aware of the cultural implications of recent scientific developments, he remarked, 'much of the recent progress in physical processes and techniques is intimately tied up with the development of new materials which can satisfy the stringent and exacting demands of science, industry and technology. Some of the projects which might be started, besides studies of the properties of materials under high temperatures and pressures, are refractory materials, binary and tertiary alloys, vacuum tubes, synthetic optical crystals, photo-conducting materials.' (Kitchlu, 1964, p. 4.) Kitchlu's proposal for a department of materials science needs to be discussed in detail within the context suggested above. Implicit in his suggestion that the NPL needed a materials science division, lay a belief that industrial research in physics needed a structural equivalent to synthetic chemistry.

IV

The development of materials science was basically a postwar phenomenon which involved the theoreticization of a series of still empirical technologies like ceramics and metallurgy under the impact of solid state physics.

Until the beginning of World War II, ceramics was basically a technology concerned with the production of whiteware, i.e. domestic table ware, sewage pipes, electrical porcelain, etc. The raw materials used in ceramics were essentially mineral in origin and the formulas for processing were considered a secret and passed on from generation to generation. The technology was largely empirical, that is, it was knowledge-based on experience rather than formally articulated principles. So long as the demands on the materials were less than critical, the requirements could be met by the then known technology. This remained the situation prior to World War II. By the nineteen-forties, Ceramics was a technology in tremendous flux, a state of things brought about by the requirements of wartime communication electronics and accelerated further by the later demands of space exploration and nuclear fuels. These demands transformed the entire culture of ceramic manufacture, differentiating it into traditional ceramics, basically whitewares, and the new synthetic ceramics catering to the demands of nuclear energy, communication electronics and space exploration. The production of these new ceramics could no longer be left to the ordinary whiteware manufacturer, who had merely to control the bulk surface of the product. It demanded control of the atomic structure as well and this requirement necessitated the services of the solid state physicist. The liaison between the solid state physicist and the ceramist was not easy. Up to the late 1940s, practically the only use of ceramics was in refractory bricks, sewage pipes and whiteware. But the new ceramics technology had grown so explosively that the traditional ceramist had only a meagre knowledge of the materials required by physicists. 'By the fifties, mission-oriented government agencies were clearly faced with a fantastic set of materials, problems and challenges. New weapons-systems and new propulsion schemes, new materials to resist high temperatures, pressures and aggressive environments, all placed excessive demands on the old ceramic technology, and its limited materials.

The need for new materials was the common factor for jet aircraft, missiles, nuclear reactors and communication devices. (Harwood in Roy, 1970, p. 5.) The need for such new materials was growing much faster than the knowledge of the properties of these materials. Most of the requirements of these new materials were based on micro structures of which the ceramist was oblivious. He had to learn about grain size, pore volume, impurity amount, etc. In order to understand the requirements of his variegated clientele the ceramist had to know something about these properties at the molecular level, which demanded a complete change in the curricula of technology at the centres for technology. The empirical bias had to go and this change did occur in the nineteen-sixties. One has merely to compare textbooks and publications written in the sixties with those brought out thirty years earlier to see the profound transformation, a movement from empirical techniques to an emphasis on theoretical principles. In fact, W. D. Kingery's standard text *An Introduction to Ceramics* can be virtually dubbed a treatise on solid state physics.

The relation between solid state physics and metallurgy was a more amenable one. Julius Harwood remarks 'dislocation theory, point defects, atomic mechanisms, and electron microscopy (that is a combination of new theoretical constructs and new techniques) helped create a new breed of metallurgists who mingled amenably with the physics community. The hybridization of theoretical concepts from solid state physics, with the new requirements in research technology, primarily the electron microscope, transformed metallurgy into a new truly cohesive interdisciplinary science, a science of structure-sensitivity.' (Harwood in Roy, 1970, p. 4.) Out of the impact of solid state science on ceramics and metallurgy, a new discipline was emerging: Materials Science. Even in its vaguely discernible outlines it signalled the rise of a new kind of knowledge system challenging the old attitudes towards science and technology. It involved, first of all, a transformation in the nature of technology, a movement from traditional techniques to one based on formally articulated principles. It also opened new avenues to the technologist. The earlier approach of the technologist was basically a macroscopic one. The technologist took his materials for granted. He never bothered to think of applications that went beyond materials such as stone, fireclay, cement, biological materials or a few alloys.

Molecular engineering changed all this. As von Hippel indicates, it was a new way of looking at engineering problems:

Instead of taking prefabricated materials for granted and trying to devise engineering applications consistent with macroscopic properties, one builds materials from atoms and molecules for the purposes at hand. This approach gives the engineer a true spiritual connection with modern science, a partnership and a freedom of action. He can conceive of devices based on ideal characteristics and then returning to the laboratory inquire how far such characteristics could be made to order. He can play chess with elementary particles until new solutions become apparent. (von Hippel, 1956, p. 316.)

The technologist, instead of accepting nature, can emulate it. The era, which Levi Strauss termed *the bricoleur*, was over.

But it is not merely a question of the scientification of technology alone. Such a description would not indicate a reciprocal relationship. The arrow seems to point from science to technology. Materials science, on the other hand, indicates a more mutually beneficial process. It represents an almost unique coupling of science and technology, rivalled, according to Seitz, by synthetic chemistry alone:

One reason for this has been the remarkable coincidence in the new materials which are most useful for application and those which are most susceptible to fundamental scientific study because of their chemical and structural simplicity. Thus the effort to prepare materials well suited for application also yielded materials which are ideal for basic study; and basic science and technology reinforced each other. Basic science continually yields ideas for the new technology, while technology produced well-characterized materials and new scientific questions for fundamental investigations.

But it was not merely a question of the coincidence of the requirements of technology with the problem of science. The creation of these technologies was brought about by pure science but the technologies in turn would provide instruments like the computer and electron microscope which would aid the development of theory. It was a reciprocity scarcely achieved before between science and technology.

The symbiosis between science and technology as expressed in materials science challenged the old value systems and classifications of science at two levels, the conceptual and the institutional.

The rationalized links between technology and science affected the clear-cut classifications between pure science, applied science and technology. As Jacques Salomon pointed out, the changes in science since World War II have forcibly challenged the idea of pure science as a separate category and deprived the old classifications of all content. In fact, changes in science since World War II have so confused the debate on and definitions of pure science that writers have started differentiating between different types of pure science, conceding, through Orwellian euphemisms, that some sciences are more pure than others. Thus, Victor Weisskopf distinguishes two groups of fundamental science, the frontier sciences remote in application, and the not-so-pure and obviously applicable sciences. In the first category he places galactic astronomy and cosmology. In the second, solid state physics and molecular biology. Both the latter have rationalized links with technology, the first with metals and ceramics and the second with medicine. The brahmanical distinction between pure science (knowledge for its own sake) and applied (therefore impure sciences) was becoming less tenable. (Weisskopf, in Salomon, 1973, p. 79.)

However, it was not just a question of the distinctions within the category of science alone, but between science and engineering. Science was supposed to be superior to engineering because science was intellectual and technology empirical. But the new interaction of science and technology created a breed of scientists and engineers who could move with facility from one to the other, adopting in science the concerns of engineering, and in engineering, the attitudes of science. The conventional classifications positing a discontinuity between science and technology were strengthened by the fact that these activities were also conducted in separate institutions. (Salomon 1973, p. 78.) As Ben-David and Ashby have shown, science grew up in the universities and technology was confined to industry. Within the university, the various disciplines such as physics, chemistry and engineering existed as separate departments. It was an instance of the ecology of the academic system reflecting and reinforcing the various categories. The development of materials science has disturbed even this. It is a truly inter-disciplinary phenomenon necessitating the co-operation of physicists, chemists, metallurgists and engineers. Hence the continuous interaction of these various

specialists may dissolve the clear-cut boundaries between these disciplines.

Kitchlu realized that the establishment of a materials science division would help create a new culture, challenging the old discontinuities between the various parts of the scientific enterprise, a discontinuity further abetted by a geographical separation between them. With the scienticization of technology and the reorientation of the laboratory towards industry, the old division of the laboratory into two distinct divisions, pure and applied, had to go. He realized also that he had to break the existing academic organization of the NPL, its division into categories according to subject. What was required was a more flexible organizational structure. He advised the introduction of project management, which would be goal-oriented and its organization involve an interaction of pure science, applied science and technology. The flexibility of the project management structure and the continuous interaction between the various disciplines would serve to break the old boundaries. Kitchlu held that 'in a few years time the NPL would have to take up a large number of projects of a technological nature and the laboratory would then function on a projectwise basis.' (Kitchlu, 1964, p. 5.) He realized that the prototype of a successful industrial research organization is inherent in materials science. There was a remarkable congruence between the two. The industrial research pattern, with its more flexible line structure (based on project management), was able to bring about a physical juxtaposition among members of a team drawn from different disciplines such as physics, metallurgy, ceramics, metallurgical engineering, etc. The problem of materials demanded this genuine interaction between chemists, physicists and engineers. The translation from theory to material, to device was a requirement of any successful work in this area. The prototype for such a new effort was the Bell Telephones Laboratory's work on the transistor, which reflected one sinuous move from conceptualization to commercialization.

During his tenure, Kitchlu, contributed to two aspects of this new industrial research culture. First, there was his idea of project management with its flexibility permitting interaction between scientists of various disciplines. He also challenged the geographical separation, which Blackett and others posited, which an industrial research laboratory must seek to transcend. It is in this

context that one must state that Blackett's solution, while drastic, was still a managerial one. Anthropologically speaking, it accepted the categories of the system. It tried in fact to reinforce them. It visualized pure science, applied science and technology as three categories conceptually. Blackett then physically separated them as three distinct elements. Basic science was assigned to one part of the building, applied science to another and production to a third. A conceptual separation of pure science, applied science and technology was reinforced by an ecological one. The current value system of science accepted the discontinuities between the three. Blackett's solution served to reinforce it. Because of this, the Blackett Report, while emphasizing the cultural contradictions inherent in industrial research, never resolved them into a creative synthesis. Mark Hannay of Bell Telephones, an industrial research laboratory which pioneered materials research, remarks 'in a university organization academic disciplines are physically separated, each department being housed in a separate building. In an industrial research laboratory, they are all physically juxtaposed together in one building, sometimes distributed within it almost randomly. The net effect of this randomization is to make people with different backgrounds neighbours, and this greatly increases the probability of interaction between them.' (Hannay in Roy, 1970, pp. 29-30.)

V

In a paper on applied research Harvey Brooks observed that a frequent paradox in government laboratories is the contrast between the high standard of scientific performance of research workers and the poor results achieved by the institution as a whole.

What usually happens is that these government laboratories (with such titles as National Industrial Research Institute, etc.) are set up to fulfil the objectives of a factory of technology, but are then organized along the lines of university laboratories. Consequently, these scientists think that they are working for a research laboratory, and as a rule that is what these institutions are called, and so take it that it is their duty to produce good science, which is what they do. On the other hand, they do not manufacture technology, which is why the institution was set up, and it is therefore not surprising that such a body should fail in its essential purpose. (Brooks, 1967, p. 46.)

The various evaluations, from Blackett's to Kitchlu's, were coming to conclusions similar to Brook's keen observation, that scientists in industrial laboratories think they are called upon to produce good science, when in actual fact they are expected to produce technology. It was this misconception that the third CSIR report set out to remove by emphasizing that the basic thrust of an industrial research laboratory was technological.

As a policy measure, the Committee asserted that the basic change required in the CSIR laboratories was an increase in the proportion of applied to fundamental research. The Committee (Charles Goodeve, Prasanta Mahalanobis, S. Dhawan, S. R. Sengupta) approached the problem in a wide historical context by observing that one of the major events of World War II was the movement of university scientists, who had spent their lives in pure science research, to mission-oriented industrial research laboratories, where they were able to change over to applied or fundamental work associated with practical problems. The scientists in these laboratories made an enormous contribution to the country's needs. One has to merely recollect the Los Alamos research group or the achievements of the Radar Research group at M.I.T. The Committee observed that this transition was achieved not through coercion but by motivating the scientists who were made to appreciate what was required of them. The Committee hoped that similar socialization would be achieved in India. (CSIR, 1964, p. 14.) Implicit in the report was a recognition that the mission-oriented industrial laboratory was an organization distinct from the university. Tied to this was the realization that the relation between pure and applied science is inextricably linked with the institutions in which they are carried out. The report revealed a major attempt to understand the uniqueness of industrial research as an activity, and to separate it from the pursuit of science in the university. There was a growing belief that the university was the home of pure science and that the basic thrust of an industrial research laboratory was technological. The report emphasized that the university, oriented as it is to basic science, must provide the standards of scientific excellence, and the industrial research laboratory the motivation in practical matters for people who are products of the university. It was in this context that the review committee revised the taxonomy of science, breaking it into three categories; science was differenti-

ated, and applied science merged with technology. The classification was as follows: (i) *pure basic*, where the object was basically the advancement of knowledge; (ii) *applied or technological*, where the object was envisaged in terms of a new plant process, product or service; (iii) *objective basic*, which was to provide knowledge on which to base technological advances. (CSIR, 1964, p. 25.) The report emphasized the importance of pure basic research for India. Recognizing that such research was the prime source of departures from orthodox practice, it underlined that, by its very nature, such research should match world standards. This was particularly important in the context of teaching. 'University teachers train people for the future, and their students must not only know what is the proper standard of research but also in some fields be thoroughly up-to-date. This is one reason why pure basic research and the universities are normally found together. The other is that pure basic research functions best in the atmosphere of the healthy university, where it does not have to be related to immediate economic objectives.' (CSIR, 1964, P. 25.)

The report then went on to emphasize that technological research was the major responsibility of industrial research laboratories, and its success had to be measured in terms of the contributions it makes to the national economy. It is here that science interacts with business enterprise. The report, however, realized the contradictions inherent in an institution halfway between the university and the factory and remarked, 'thus one is faced with the conflicting principle that basic research is best carried out independent of the user, but the best application or research occurs when it is as close as possible to the user.' (CSIR, 1964, p. 26.)

The third Review Committee held that,

While basic research should be left to the universities, objective basic research, undertaken in order to fill a gap in basic scientific knowledge in a field of potential practical importance or to extend the area of understanding and application of the industrial process, should be the primary interest of the CSIR laboratories. Standing as it does between the extremes of *applied developmental research* on the one hand and *pure basic* on the other, objective basic needs workers who are a combination of the intellectual and the practical. This type of research is not merely routine but must be provided with facilities, atmosphere and treatment required for all creative work.' (CSIR, 1964, p. 26.)

It is in the context of these recommendations that the specific proposals on the NPL should be read.

The report endorsed Blackett's view that greater emphasis should be placed on applied research. This applied work, it felt, should develop around the principal divisions of the laboratory. 'Apart from standards and testing, we recommend support and encouragement to the vigorous radio components and ceramics pilot plant and to the radio propagation unit.' (CSIR, 1964, p. 34.) The report added that the sections on electronics, acoustics, optics and industrial physics also deserved encouragement.

As regards basic work in the NPL, the report reiterated its fundamental recommendation 'that the bulk of the basic work of the CSIR laboratory should be related to and form the background of its applied work. This is particularly true of the NPL where there are wide and exciting possibilities in this direction. However, at present, largely for historical reasons, there are groups in the NPL which are concerned with pure basic work, with little or no connection with applied work. We feel that this emphasis should be changed over a period of time towards applied work as recommended above.' (CSIR, 1964, p. 35.) The Committee refused to wade into the intricacies of the issue but merely formulated two basic principles regarding reorganization:

1. that research laboratories should not be formally divided into two wings, pure and applied. This results in isolation and intellectual snobbery. Matters are made worse if the two wings become administratively separate with two separate Directors.
2. If the centres of advanced studies are to be set up in any scientific discipline, such as physics, they should be set up in the universities and not as part of the CSIR establishments. CSIR can be great assistance in the formation of these units and in other ways, but the universities are the natural and appropriate homes for advanced studies. (CSIR, 1964, p. 35.)

A further clarification of the nature of the NPL as an industrial research laboratory was obtained in K. R. Ramanathan's first Krishnan Memorial Lecture in 1965. Ramanathan provided an incisive portrait of a mission-oriented laboratory by emphasizing its three basic characteristics— (i) interdisciplinarity, and close interaction between basic research and application; (ii) the methodology of precipitating and organizing coherent effort around big problems; and (iii) their ability to adapt their goals to

the requirements of sponsors. Ramanathan even emphasized that the roots of this revitalized NPL could be traced back genealogically to Krishnan, for Krishnan was clear from the start that a developing economy like India should have an organization modelled on the U.S.A.'s National Bureau of Standards (NBS). Krishnan, he stated, was aware that 'science and technology were mutually dependent and act and react on each other. Science for its growth requires technological aids and new technology grows out of it.' (Ramanathan, 1965, p. 56.)

Ramanathan pointed out that Krishnan's conception of the NPL during his directorship was influenced by his understanding of the NBS in the USA. The functions of the NBS were (i) development and maintenance of international standards of measurement and the provision of means and methods to make this possible; (ii) the determination of physical constants and the properties of materials; (iii) development of methods and instruments for testing materials, devices and structures; (iv) advisory services to government agencies on scientific and technical problems; and (v) the invention and development of devices to secure the special needs of the government. (Ramanathan, 1965, p. 56.)

It is interesting to follow Ramanathan's reading of NBS objectives, for it parallels Kitchlu's critique of the NPL, Delhi. Ramanathan emphasized that the first thing a mission oriented laboratory demanded was a statement of objectives; 'it puts down the outlook and objectives which are required to meet the needs of the country'. These included, in the case of NBS, 'the development of materials, means, methods and devices for special purposes'. Ramanathan then pointed out that 'in the objectives of NBS, there is no division of work according to disciplines; it does not say whether the work is chemistry, physics or engineering. It does not separate metallurgy or physical chemistry or ceramics from each other' (Ramanathan is obviously referring to NBS's materials division). (Ramanathan, 1965, p. 56.) Ramanathan then outlined how an NPL organized on such a basis would tackle a task, pointing out that a considerable amount of thinking was going on regarding the development of electronics and the radio industry in India. 'The growth of a really worth while electronics industry to meet the needs of all our services including defence and communications and broadcasting would require a large amount of work by large groups of people and it would require a study of

materials, techniques, instrumentation and production of standard equipment.' (Ramanathan, 1965, p. 56.) Ramanathan felt that it was in a widely encompassing field like this that the various divisions of a laboratory like the NPL would continue and do valuable work. Looking critically at the NPL, Ramanathan remarked 'I think we have, to some extent, incorporated parts of this in the actual working of the NPL dealing with indigenous manufacture of radio components and materials, but we cannot say we have kept in mind all aspects of the NBS.' (Ramanathan, 1965, p. 56.)

Criticizing the existing organization, Ramanathan observed, 'that there are far too many divisions in the laboratory and it would be a good thing if different related divisions could work together on a common project. . . . Problems that come up for solution cannot be dealt with by one particular division. I think probably more can be done by co-ordinating the activities of these related groups for solving the problems that come up before the laboratory. In some of our bigger laboratories, we have a collection of facilities which we do not have in many university laboratories and it is important in this connection that this combination of facilities be made use of in the fullest possible manner.' (Ramanathan, 1965, pp. 56-7.)

VI

In 1965, the objectives of NPL were as follows: (a) to undertake applied research on all physical aspects with a view to helping industry; (b) to undertake basic research in fields which have a bearing on problems of a physical nature; (c) to undertake developmental testing to help industry; (d) to maintain basic standards of mass, length, time and temperature, as well as derived standards of electricity, acoustics and optics. (NPL, 1965.)

P. K. Kitchlu resigned as Director soon afterwards because of differences with Zaheer over the personnel policy to be followed by the NPL. The laboratory was once again bereft of a Director, and Zaheer assumed the task of orienting the laboratory towards industrial research. One of the first things he attempted to do was to insist on project management. The systematic formulation in terms of goals, budgets, time and personnel that project management demanded, was something that the scientists of the NPL,

unused to accountability of any sort, found difficult to attune to. It was precisely this fact that had left aghast the Parliamentary Estimate Committee, which had decided to investigate the NPL. Its basic disappointment lay in the fact that the laboratory had not acquired the management orientation that modern industrial research required. The first lacuna it referred to was the absence of formalized project management.

The Committee pointed out, 'It is usual for every research laboratory to draw up in detail its annual research programmes, indicating the number of items to be taken up during the year, the objectives, the scientific personnel and equipment required, time targets, etc.' (Estimate Report, 1966, p. 29.) Such programmes, the Committee pointed out, were then presented in the form of project reports, for consideration by the scientific sub-committee and the executive council of the laboratory, and it was only after securing approval that the laboratory embarked on its programme. In his statement before the Committee the Director-General, Hussain Zaheer, explained that he had held a conference with the scientists to reiterate the importance of project management. Zaheer found that the scientists generally took for project headings textbook phrases like 'a solid state physics project'. Zaheer told the scientists that this was not a statement of the project. 'You have to enunciate what you want to do in a solid state physics project, why you want to do it, how long it will take to do it, what stage you will reach after one year, two years and so on. This is the methodology of putting your problems in the form of projects; only then does the scientist know what he is doing and arriving at. It does not stunt his initiative or individuality, it gives more direction to his thought and thinking.' (Estimates Report, 1966, p. 27.) Zaheer added that in June 1964, the NPL's programme was recast on a projectwise basis, with time targets. Zaheer, however, cautioned the committee, stating 'we must give them some time. They are now working on these lines. I personally am quite satisfied with the basic change they have made. They have formed advisory panels of scientists and industrialists to scrutinize each one of these projects. The research programme of the NPL was formulated in June 1964, reviewed in 1965, and modified to some extent and is now moving forward.' (Estimates Report, 1966, p. 27.)

The Parliamentary Estimates Committee to which Dr Zaheer

presented his plea was not satisfied. The Committee claimed that the reorientation of the NPL to industrial research was phlegmatic. It pointed out that, while drawing up the research programme for 1964-5 the executive council observed in April 1964 that 'the programme of work drawn up at present was not quite clear and that it should be recast on the basis of detailed information such as objectives of the project, personnel, apparatus, present stage of work, future lines of work and the probable period required for completion of work.' (Estimates Report, 1966, p. 30.) In this context it also added that the scientific sub-committee of the NPL had suggested in June 1964 that project reports must (1) have a code number, which would indicate the nature of the project, typed according to whether it was fundamental, applied, developmental or purely routine; (2) mention the royalties and test fees earned, division wise; (3) indicate the contribution of each project to the national economy either as regards finance, additional knowledge or technical know-how. The sub-committee also added that the basis on which these conclusions were arrived at should be stated. The scientific sub-committee further cautioned that projects should not be undertaken merely for the publication of papers but should have as their goal, industrial application. (Estimates Report, 1966, p. 30.)

During the course of its inquiry the Estimates Committee wished to know the expenditure incurred by various research projects in the NPL. The NPL representative admitted that 'the laboratory had not been maintaining separate accounts of different research projects' and confessed that no indication could be given of the amount of expenditure incurred on them. On further questioning, the representative admitted that 'the method of accounting in the NPL is completely wrong. The present procedure leaves a person without any knowledge as to what has been spent on a project, whether the expenditure has been infructuous or has resulted in any return.' (Estimates Report, 1966, p. 33.) The representative added that the NPL was reorienting its accounting system. It was in this context that the Estimates Committee referred to the suggestion made by the Zuckerman Report that, in the control of applied research or development, an assessment of the results achieved and of likely future progress should be undertaken at intervals of not less than three to six months. These results, they added, should not only be made

available to the higher management but also encourage cost consciousness in those responsible for individual projects.

The planning of industrial research, as we have clarified, presupposes the introduction of project management and accounting systems. This demands, in turn, a proper classification of the various elements of industrial research which could then be evaluated in terms of quantitative indices. It is in this context that the Committee questioned the classification of research in the NPL. It pointed out that its research work was still differentiated as applied and basic. The Committee held that such a rudimentary classification would no longer do and recommended adoption of the system suggested by the Zuckerman Committee on 'the management and control of research and development.' (Estimates Report, 1966, p. 22.) It postulated a five-fold classification of research, as follows: (a) *pure basic research*, which is carried out solely in order to increase scientific knowledge; (b) *objective basic research*, an intermediate category between pure and applied, denoting basic research in fields of recognized, potential technological importance; (c) *applied project research*, aimed at attaining a practical goal which can be precisely defined, such as a new process or a piece of equipment; (d) *applied operational research*, directed towards improving the use of an existing process or piece of equipment; and (e) *development*, to bridge the gap between research and production. It may be defined as the work necessary to take a new process or piece of equipment to the production stage. It will often include the creation and operation of pilot plants and the construction of prototypes.

The Committee asked the NPL representative about the relative allocation of effort and expenditure devoted to pure and applied work. The representative admitted that no such classificatory system was followed in accounting, and that the NPL could not, at that time, provide an accounting system in terms of the categories mentioned above. (Estimates Report, 1966, p. 22.)

It was in this context that the Committee approached the relation between pure and applied research. Zaheer had stated before it that the NPL did possess several theoretically oriented groups and added that the current policy division 'was that 80 per cent of research would be applied and 20 per cent would be theoretical'. He contended: 'We believe that without a certain amount of basic work, standards of work in the applied sciences

come down'. Zaheer referred to pure research as an intellectual tonic: 'As long as it is of a good quality it should be continued'. (Estimates Report, 1966, p. 23.)

In its report the Committee systematically reviewed the entire debate, running the gamut from Blackett to the CSIR Report. It then echoed the contentions of the Zuckerman Report which stated that pure research was best carried out in the university rather than in a government establishment. The Zuckerman Report had added: 'We do not agree that government research establishments should undertake basic research work just because it might help recruitment and provide intellectual stimulus for the staff. Indeed, if the promise of such work becomes an overt inducement to recruitment, we suspect it would lead only too often to so-called fundamental work being pursued in a backwater, remote from the mainstream of scientific activity and with little concern with practical activity, and that in the long run it would neither help nor provide intellectual stimulus.' (Estimates report, 1966, p. 23.) The Estimates Committee then remarked that the NPL's orientation to industry seemed an indifferent one, for despite the recommendations made by the third CSIR Review Committee and the opinions of Blackett, the NPL had made no conscious effort to shed its pure basic work. The Committee advised that a systematic effort be made 'to reduce the quantum of basic research work required to the minimum necessary for supporting applied research'. It added that detailed data must be kept about the ratio of pure to applied research in the NPL so that some index of the laboratory's movement to industrial research might be obtained.

Against the background of the debate between pure and applied science and the absence of appropriate management orientations in the NPL, the Committee felt that the work of the national laboratories should be incorporated into the planning process, insisting that priorities of research in the NPL synchronize with the social priorities of industrializing India. The Committee observed that the choice of problems in the NPL was totally isolated from the planning process. It cited the following comment of third CSIR Committee:

At present research programmes of the institutes are inevitably based on ideas arising internally with the Director and the research staff. A lacuna

arises in the lack of impact of ideas from people outside. The position can be improved by contacts with the departments of planning and industrial development, and familiarity with the short-term and long-term programmes of industry and the association of scientists from industry in the framing of research programmes. This would enable forward-thinking and anticipation of the research requirements in their relation to plans of industrial development. (Estimates Report, 1966, 25.)

The Director-General of the NPL, Hussain Zaheer, countered by claiming that the CSIR had been persistently requesting the technical development wing and the Planning Commission to indicate the problems which they would like the CSIR to solve. 'Till about 1962-3 the reply invariably was that we were catching the wrong end of the stick, that all that they were interested in was that on suitable occasions, especially on the licensing committee where we were represented, we should tell them that these are matters on which we would supply them with technical know-how and they need not give it to any outside party.' He also complained that 'no systematic machinery existed to obtain information from government about existing deficiencies and the kind of research required. Given this', he admitted, 'the selection of research problems had been ad hoc so far.' (Estimates Report, 1966, p. 25.)

The Committee countered by stating that when the Fourth Plan proposals of the NPL were drafted they were not oriented to even such a broad categorization as the needs of defence, import-substitution, export-promotion and promotion of indigenous know-how. The Committee demanded that the study group of the Planning Commission should be provided with such vital information as the number of projects under the various categories mentioned above, their significance to the national economy and the time-targets decided on. It added that these statistics were important for the NPL itself, as an organization, and would help give it some feel of physical targets to be attained. The Committee observed that the procedure followed by the NPL and other CSIR laboratories was faulty and asked for a revision so as to enable planners to examine the programme of each laboratory in the context of the economy. However, it accepted Zaheer's complaint that, 'neither the Planning Commission, nor the Ministry of Industry, nor any other user department, has indicated specified areas, where the potentialities of the NPL could be fruitfully exploited during the Fourth Plan. The Committee deplored the

lack of contact between the NPL and the potential users, even among government departments.' (Estimates Report, 1966, p. 38.) The NPL representative assured them that the categorization in terms of national priorities would be followed by the NPL.

By the Fifth Plan Period the laboratory was in fact proclaiming its new research orientation and its annual report for 1973-4 makes interesting reading. The laboratory claimed that 'its objectives had been critically reviewed and very thorough planning of the activities for the fifth five year plan was done in view of these objectives. An exercise on SWOT (strength, weaknesses, opportunities, threats) analysis was done, and priority areas in which the laboratory had established expertise and competence were identified for the thrust in years to come'. The laboratory was also reorganized on a new basis in accordance with the newly stated objectives. The redefined objectives of the NPL were 'to strengthen and advance physics-oriented research and technology and to assist in their effective utilization for public benefit'. The objectives were enumerated as follows:

1. Custody, and the development of national standards of measurement at internationally accepted accuracy, and research on standards and new techniques of measurement.
2. Periodic calibration of standards of instruments and equipment used by various governmental and other testing authorities and industries, against national standards.
3. Calibration of instruments and the testing of industrial products, and their application for performance, life, and their effect on environmental conditions.
4. Undertaking applied research, design and development work in physics-oriented technologies with a view to improving, adapting and developing indigenous and imported technologies. These areas included solid state and electronic materials, such as semi-conducting, electro-optical and luminescent types and their devices, micro-wave components, circuits, subsystems, and instruments, thin and thick films, reprographic display, and control and measuring instruments, cryogenics and super conductivity, vacuum-technology, high-pressure technology, carbon technology and glass equipment and apparatus.
5. Undertaking basic research on standards, radio science and in areas of applied research and development indicated in 4 above

and in emerging areas of physics.

6. Providing technical advisory services information, extension, consultancy and training, collaboration with the university and other organizations.

In the reorganized NPL, apart from standards, the basic technological thrust was to come from two divisions, those for materials science and specialized techniques. The division of materials science incorporated the old electronic components and carbon technology divisions and their two pilot plants. The department of specialized techniques was to cater specially for the department of materials science and the complementary relation between the two was recognized in the report itself. 'In the second industrial revolution through which we are passing, which is sometimes referred to as automation, increasing demands are being made on scientists and technologists to tailor materials to required specifications. The specialized techniques group undertakes the testing of materials for purity, crystallinity and perfection and also undertakes precise measurements of the physical properties of materials.' (NPL, 1974.)

One must now ask how the scientists reacted to the transition. They refused to submit to a questionnaire, many of them contending that the CSIR already sent enough of them. However, they agreed to participate in dialogue viewing self-critically the nature of the transition. Their observations were restricted to the movement from pure to applied science and the pressures of relevance. Most confessed that the change towards applied science was externally imposed and also emphasized that the commercialization of science had disturbed the normative system of the organization. This displacement, from the paper as gift to the patent which commanded monetary royalties, had disturbed the organization. Applied science lacked the referee systems of pure science. These issues are discussed in the three interviews reproduced below:

Interview 1 : The NPL in those days was more like a university. Krishnan hardly interfered with the work of the scientists. He is reputed to have said that a scientist who does not work digs his own grave. This atmosphere continued as long as Krishnan lived. But after he died, questions began to be asked about what the NPL had done; you see, the NPL began with great hopes that were not fulfilled. Under Krishnan we were mainly involved in pure research. Of course we did a bit of testing on

the side. But with the Blackett Report things changed.

The Blackett Report had a discouraging impact on the organization. I do not know what exact yardstick Blackett used but in general he pointed out that most of the units in the NPL had failed. He somehow seemed to confirm the questions often asked 'Of what use to India are three papers in a foreign journal?' Blackett believed that the NPL should stick to its objectives. The Report in general seemed to insist that applied work of a non-sophisticated type which had some use, which made some contribution to the country at large, was better than marginal contributions to fundamental science. The impact of the Blackett Report took some time to percolate to us. In fact, they appointed another committee to look into the Report, which in government circles is a polite way of shelving it. But it jarred the organization, made us take things we were not prepared for; a lot of us were disappointed with Blackett's Report. It is true that some of the work we did was not in line with certain objectives, but he failed to consider its intrinsic worth. I do not approve of his strictures and recommendations. But I accept it. After a time, most scientists as they grow older realize that few can make a contribution to pure science and, let us admit, that the NPL began with great hopes it did not fulfil. We have failed as pure scientists.

After Blackett, the NPL seems to have become not socially conscious, but publicity-conscious. We began taking on things we weren't competent to do, to make instruments which were beyond our capabilities. We reacted too quickly and took projects which might win us applause without considering whether we were competent to complete them. It's not making gadgets that really bothers us, it is being forced to seek applause. Gadgets are incidental. If they get applause we have to make them. We are no longer catering to science but to a different audience.

Interview 2: Krishnan was by training a university professor, a pure scientist. It is true he helped start the work on ferrites, but he was essentially a lover of basic physics. I don't know whether he would have fitted into the present mood of the times. He was a university professor and as such would have found it difficult to fit into the research and development work we are doing now. It is true he was intelligent enough to contribute to anything; he had the acumen. But he belonged to the school of Raman. By personal liking, he was a physicist, a man who would like to unravel one more property of a diamond rather than worry about its productivity. They asked me to do applied work once, but I refused. Of course the director has been very co-operative. He has given me a little table, allowed a motivated few to pursue pure science. It is not that applied science is bad. We need it. But I think pure science should not be ignored. They should pick the best, the elite few, the motivated ones, and

let them pursue it. The rest can be lined up to join the democratic forces (laughs).

I joined the laboratory in 1948. Krishnan died in 1961. That's thirteen years. There were no questions up to 1958. Then they began to hover in the air, whether the investigations in the NPL were benefitting the man in the street. Till that time, the questions at promotion time were about one's academic achievements. Nobody bothered to ask you whether you had made an appliance. There was no political pressure at that time. Around the sixties however questions began, and by the seventies they have become increasingly important. But this is a global phenomenon. Even in the U.S. they are asking these questions. We, here, are years behind. Yes. Science is no longer an esoteric subject intelligible to a few Cambridge dons. This kind of attitude is not relevant anymore. I am a basic scientist, a mathematician by training, but I feel I have to make my work relevant. It is as Oppenheimer said, 'We need new knowledge like a hole in the head'. Our knowledge in pure science has become too saturated except in a few fields in mathematics. We have to show people the uses of knowledge and in this lies the value of science. But in Krishnan's days, we had superb papers in international journals. You won't find any cosmologists in this laboratory, possibly only in the TIFR.

I think the point of change was the Blackett Report. The separation of basic and applied physics started at that time. The utility of an investigation became the criterion. People were referring to laboratories like the road research institute whose effect was immediate and whose impact the man in the street could comprehend. In physics the effect is more indirect and difficult to explain to the common man. The questions began: all other laboratories have started doing this kind of work. Why not the NPL? When Thacker was the Director-General, he also said this. He said that, apart from a few motivated scientists, all the rest should do applied work. I forgot to add, Kitchlu also had an impact. He was an applied science man himself. He runs a factory for optical goods now. Preference is slowly given to technologists now. But our rulers are pure physicists, they have to cater to the people, but by training and taste, they are pure scientists. Our director himself is a university man forced to introduce technology. Many people have turned over and adopted this new approach. I remember some student, some idiot who once asked a famous scientist to do some technological work. You know what he said? 'A baker should remain a baker, an artist should remain an artist'. I have not done applied work. I would rather do functional analysis, discover hidden harmonies. I admit basic research is a luxury; a search for harmony and beauty is. Our country needs applied science. But a small percentage, a select few, must continue basic work.

I think a scientist should be an ideas man. But now he is asked to go to

the pilot plant stage, and then hand over from there. He should confine himself to ideas which he has confirmed will work. The problem of industrial adaptability is the engineer's task. As a physicist he is meant to create new ideas. There ends his act. It is for the industrialist and the technologist to take over from there.

I admit the NPL is not the place for cosmic research, but pure science could be gauged. The yardsticks of pure science are the yardsticks of international science. The referee system is tight. I do not know whether we have developed a system for applied science . . . we can, but we haven't.

Interview 3: Here they don't appreciate or understand or encourage fundamental science anymore. They say, 'do science for the market'. If they want toys, why don't they ask the mechanic or the engineer. When you bring in the market you bring in the money, you bring in royalties and the worst kind of people. You bring in non-cooperation. People say why do fundamental research when the other man gets money for simple things? This creates a bad atmosphere and I am against it. When a man publishes a paper he does not care about market evaluation. The request for reprints is reward enough. With patents, this spirit is going.

A paper is an open thing. It is public knowledge. But the trouble comes when the commercial element enters. It is only in doing something directly for money that the worst in a man comes out. In royalties, the soul of a man gets sold. Earlier we used to co-operate, now we have competition. People try to keep others out of the team so their share of royalties is higher. It's happening here and at CEERI.

Before, the only group that did such applied/technological work was the electronics group. Now it has spread. Because of this, teams have broken up, even friendships. People want to do something only if it has market value. Even the authorities have begun to emphasize the market value of products. They insist on catering to lower tastes.

A paper is an open thing. A paper goes to the scientific community. It has to be published. It can be challenged. Its worth can be gauged. Who bothers about a patent? A paper can be gauged by the amount of people who quote it, the number of people who demand reprints. Of course it is a relative thing. . . who reads patent advertisement? They are so vague. One can hardly find out what they are meant for. There may only be a difference of a screw but who bothers. They don't define what a patent is. Patents have no meaning. The description is so vague.

He showed me an advertisement to demonstrate the possibilities of cheating and entering into a number's game. 'Here is a circular. There are four patents listed here. Actually it is one patent referring to the same object at four temperatures. He calls it four

patents. So when the time for promotion comes, he can claim to have taken out four patents instead of one.'

VIII

By the late nineteen-sixties, the NPL was gradually phasing out industrially irrelevant problems and concentrating either on basic-oriented or applied research. The relationship of science to technology however remained problematic, and the fundamental controversy centred around the establishment of pilot plants. The scientists were reluctant to establish pilot plants because they felt that production efforts would overshadow research in the laboratory. To a certain extent their fears were valid. As a scientist in the aggressively technological, electronic components group explained,

We were a camel unit. At the expansion stage we needed money, people, and space, and they were not willing to give it. There was a technical block at that time. It was allocated to the stores section. We salvaged a bit of space there for ourselves. Then the stores were displaced to the hangar, and we added our ferrite sheds and soon extended to six technical blocs. But beyond a point it becomes difficult to expand. There is a physical limit to the laboratory, to the water, power and space allocated to it. If the NPL was given 500 kilowatts of power, we consumed 400 of it. We even had our own tube-well. (Interview, 1976.)

But the scientist's reluctance regarding pilot plants was not based merely on the apprehension that the production element would overshadow research in the laboratory. There was a second reason. The scientists felt that once they had made a successful sample in the laboratory, their job was done.

We had several discussions on this. I tried to explain to them that one prototype may solve the problem but only partially. You have to produce it in numbers and that too within a particular range. You cannot undertake research and development solely on the laboratory bench. I was able to show them the variations between various laboratory batches. In batch production, there is a slight variation from batch to batch, which cannot be totally controlled. But we must ensure a repeatability of at least 80 per cent. The problem of quality control in batches also becomes vital. The crucial parameters of atmosphere, pressure and temperature have to be controlled. It is only by doing this in quantity, in bulk and studying the variations, that you can arrive at the norm. Then, and only then, can you

pass it on to the entrepreneur. All this necessitates pilot plant activity. (Ramamurthy, interview, 1975.)

An industrial research laboratory without a pilot plant is an amputated entity. A pilot plant is an attempt to stretch science on to the production line. It necessitates a collaboration between the scientist and the technologist and it is this that remains the most pressing issue at the NPL.

A technologist explained the case thus:

A scientist does not understand the problems of technology. One of my plants was not giving me proper purity. All they could offer were a hundred hypothetical solutions, but none that could work. They can't pinpoint the defect, and say, 'Do something like this'. I am not working on a little piece and tabulating my results. That is the stuff of which a paper is made of. I have to make 50,000 pieces. I have to scale up the whole thing, which the scientist is not capable of doing. A scientist takes his one inch sample and talks of absolute conditions. But there is a difference between absolute ideal conditions and production conditions. I have to compromise ideal conditions in order to obtain a product. But the scientist sees this as a violation of something pure. (Interview, 1977.)

But behind the tensions in the perception of the engineer vis-à-vis the scientist, was the more intense problem of career mobility in an industrial research laboratory. Dr Kamalesh Ray of the CSIR personnel division has observed that 'research organizations are plagued with an artificial and arbitrary classification of posts into scientific and technical' (Ray, 1973, p. 189). Ray stated: This administrative wedge has created a caste system among scientists in the laboratory'. The career lines were as follows:

Senior scientific officer (Grade I) 700-50-1250

Senior technical officer (Grade I) 700-40-1100-50-1250

Junior scientific officer (Grade II) 400-40-800-50-950

Junior technical officer (Grade II) 400-450-30-600-35-670; Evaluation Board-35-950

This classification, Ray pointed out, was based on a premise that equated science with research and technology with non-research. This arbitrary definition has put pilot plant scientists and engineers into technical scales. Ray added: 'In a developmental research organization, the more useful personnel in development, design and pilot plants are pushed down into lower cadre. This artificial distinction was further complicated by the peculiar history of

technology-oriented groups in the CSIR' (Ray, 1973, p. 189).

A scientist in the ferrites section stated the problem in the following manner:

For years, ours was a science that did not believe in production. The scientist with the Ph.d. believed that the paper was his basic product. The university remained the Mecca of Indian Science. So technology, when it began in the NPL, began with groups who were high on experience and low on academic qualifications, mainly B.Sc. They sustained it through its earlier, leaner years. Today everyone is jumping on the technological bandwagon. Given the Indian fascination for degrees, these older people feel threatened. The director will have to mediate between the two groups. Franz Kiss was a prime example of the old cadre of technologists, a man who had not studied up to the tenth class—he established one of the finest glass technology units in Asia. (Interview, 1977.)

As an example of such discrimination, the head of the electronic components unit cited the case of R. Krishnan who, as a technical operator, had done valuable work on capacitors.

When the NPL and the NCL were created, all the scientists from the director down came from the academic world. The committees that selected these scientists were also drawn from the academic world. These men sat as arbiters over industrial research. The academic world sat in judgement over the industrial. Take a cross section of any committee drawn here today and you will find most of the ingredients drawn from the university. In the NPL there was hardly any important committee with which Delhi University professors were not associated. This powerful combination of academic values and academician at the top of the power system prevented industrial research laboratories from performing their role. This committee harks back to your academic record again and again. They hardly look at what a man has done in his stay at the laboratory. Nag Chaudri and Sarvate always harked back to the fact that R. Krishnan got a third in his B.Sc. A man can grow mature after his years in college. They seem to forget this. Academic records can play a part at the moment of entry. But once a man is taken into the organization, it is his performance within the organization, his technological worth, that should be reckoned with. Krishnan started as a technical operator. He went abroad and worked under Neele, the doyen of scientists in the field. Then he applied for a post of scientific officer. But the board felt they could not give a scientist's job to a man who was a technical operator. The chairman was prejudiced, and when Krishnan heard about it, he took an implacable stand. He refused to come back. Today he is one of the top scientists at a laboratory in Paris. (Interview, Ramamurthy, 1977.)

A young engineer in the vacuum technology section was even more brutal while pointing out the consequences of this discrimination. 'A technologist has no prospects in the NPL. You linger on in the lower posts. Do you know that a large number of them have part-time jobs? Some run small machines at home. There is a man in the DPEC who sells cloth in the evening. Another is working as a teacher in an evening college. Others give tuition. Many supervisors work in factories at night, preparing designs. Teaching is very popular, at the coaching colleges littered a mile away from the NPL. There is another man who pulls a rickshaw.' (Interview, 1977.)

The relation between the scientist and the technologist came to a head when the NPL Director issued an advertisement in August 1973 for four posts at the Assistant-Director's level stipulating a Ph.d. as the basic qualification. The stipulation eliminated every engineer in the organization from applying for the post. Reflecting on this move, Ramamurthy remarked,

Somehow today the horizons of the scientists seemed to have become narrower. The earlier men might have been academicians but they had a vision, a modesty. I remember what D. S. Kothari told me a year or two back at a function. 'Ramamurthy' he said, 'you remember my comments about *Karkhanas*? I told him 'How could I forget, they still burn'. He said, I take them back. Yesterday I criticized you for turning a laboratory into a factory. Today I would be pleased if every university were transformed into one'. Unfortunately today the Ph.ds have formed into a club. It is not that I am against academic training. Without it a scientific attitude is impossible. But you can't make a fetish of it. This conflict between the engineer and the scientist, a lack of communication, is a retrograde step, especially when technology is becoming scienticized and science is moving closer to industry. (Interview, Ramamurthy, 1978.)

The furore over the advertisement would have died down under normal circumstances after the usual tremor of discontent. But the issue was kept alive and the Director forced to withdraw the advertisement as a result of the activities of the NPL branch of the CSIR Worker's Association. The problem of the relation of scientist to technologist brought to the forefront one of the most fascinating developments in industrial research—unionism.

The development of unionism in science has to be looked at within the broader context of the industrialization of science in the world at large. Krishnan and the earlier scientists were more

sensitive to the technicization of science, of scientific discovery depending on technological aids like the cyclotron, the electron microscope and the computer. But they did not perceive clearly that the scienticization of industry would not be a unidirectional process. They failed to realize that the scienticization of industry would bring about the industrialization of science. While the insights of science entered industry, the norms of industry affected science. It is this that the scientist took long to perceive.

The Association of Scientific Workers in India (ASWI) was established in 1946. At that time two associations were formed. The ASWI was established by B. C. Guha and inaugurated by Nehru. Simultaneously, Meghnad Saha inaugurated the Indian Science Workers Association. Both associations lay fairly dormant till 1961 when the Joseph episode took place.* The suicide of this scientist was to have a remarkable impact on unionism in science and emphasized also the particular problems of science operating within a culture of scarcity, as in India. The members of the ASWI in the CSIR were however caught in a definitional trap. The CSIR secretariat pointed out that the ASWI could not be registered as an association because of its trade union character. It was also made clear that the CSIR would not recognize the ASWI if its membership was not confined to the CSIR. This, in turn, led to the establishment of the CSIR Scientific Workers' Association (CSIR, SWA) in 1968.

In the formative years the membership of the ASWI in the NPL never exceeded ten. The body was still insignificant and the authorities hardly responded to it. But by 1968 after the establishment of the CSIR, SWA, its membership rose to a hundred and twenty. Earlier the CSIR, SWA tended to be risen by factional politics, a situation which may further aggravate by the enrollment of a many disgruntled scientists. But with the assumption of a

* M.T. Joseph of the Indian Agricultural Research Institute took his life in January 1961. Joseph joined the Institute immediately after completing his B.Sc. While working at the IARI he also obtained a M.Sc and Ph.d. He went abroad for further studies and returned to his post as Junior Scientific Assistant. He was drawing a salary of Rs 160 a month, of which Rs 60 were being deducted every month as repayment for a loan which he had taken for his studies abroad. Joseph applied for better jobs but his applications were never forwarded. The Haffkine Institute at Bombay offered him fairly senior jobs twice. But, since he had signed a bond with IARI before going abroad for further studies, the authorities refused to release him from the administrative trap. Joseph committed suicide on 6 January 1961.

group of scientists who commanded respect for scientific competence and integrity, the association was able to concentrate on policy issues, insist on the establishment of clear norms, and chalk out areas of relevance where the union would negotiate with the Director. One of the first successful moves of this revamped organization was to object to the personnel policy of the organization. Its cyclostyled bulletins reveal a clear picture of the industrialization of science in the NPL and the necessity of unionism. Unlike the NPL staff association, which confined itself to seminars and restricted membership only to those who were classified as scientists, the CSIR, SWA realized that the union must embrace every category from the gazetted scientist to the casual worker. It is in this context that one must look at its various moves at unionization.

The first successful attempt within the NPL dealt with the advertisement of August 1973. After pointing out that all engineers were eliminated from applying for the post, the union felt that authorities were being arbitrary in the issue of the advertisement as it was literally tailor made for four scientists in the organization. The association requested the laboratory to (1) take immediate steps to cancel the advertised posts; (2) define clearly the priority projects of importance in the laboratory; and (3) appoint an impartial commission to evaluate and assess the work of all the scientists in the laboratory. (SWA document No. 5, 1973.)

The SWA also realized that the organization structure of an industrial research laboratory contained, beyond the highly publicized scientists, a whole anonymous infrastructure composed of technical workers, auxiliary technical workers and a category that rarely finds mention in the NPL records, the daily worker. In a systematic and detailed note on career planning for junior staff it remarked:

The laboratory creates posts for higher positions oblivious of the claims of the lower technical staff. Many of the junior staff members are stagnant on the same post for 8–10 years and even more in some cases. There is no impetus for them to work. They are ignored on the plea that they are skilled workers meant only for that work. The laboratory contended that they contributed nothing to scientific and technical development, a statement that is not rigorously true. On this plea they are even denied their share in patents and royalties. (SWA document No. 3, 1973 p.1.)

But more pathetic than the state of the technical staff was the status of the daily worker.

The concept of the daily worker is something that sociologists have often associated with agricultural and industrial labour. But the NPL, which was conceived as an intellectual institution, possesses over a hundred such workers. The recruitment of the daily worker began around 1969, when the electronic components group expanded its pilot plant production. Initially they were required for fairly routine jobs such as mixing and grinding, but soon they were being recruited for complex technical operations like the maintenance of the nitrogen plant. 'These hundred daily workers are a motely crowd. Some of them have not read up to the sixth class, don't know the difference between an alkali and an acid. Some of them don't know how to convert inches to centimetres using calipers. Yet some were qualified engineers and I found B.Sc's in engineering and illiterates getting the same pay.' (Interview, scientist, NPL, 1976.)

The CSIR, SWA, in its note remarked 'The majority of persons working in the development-cum-production unit on various skilled and unskilled technical posts are being kept on casual daily jobs (at Rs 9 a day). This is a practice which has been prevalent in the laboratory for the last many years. These casual workers, in the majority of cases, are working in the laboratory without any chance of being made regular. (SWA, document No. 3, 1973 p. 2.) In fact, an Assistant-Director openly stated that this was the only way of assuring industrial discipline in a laboratory. The casual workers had taken the laboratory to court, demanding regularization, but the court ruled that an industrial research laboratory was not a factory and therefore did not come under the Industrial Disputes Act. (Interview, scientist, NPL, 1975.)

The leaders of the association realized that unionism in the laboratory was still new and that the scientist had to be convinced that unionism was not *infra-dig*. It is in this context that the NPL's CSIR, SWA bulletin quoted prominently extracts from an *Illustrated Weekly* article by V. B. Karnik to show that unionism among professionals was spreading. 'There was a time when Unionism and strikes were known only to workers in factories, mines, railways, docks. White collar employees and professional workers like doctors, engineers and professors thought it below their dignity to band themselves in unionism and yell slogans.

Today it is different. Trade unions exist among professions, so do gheraos and strikes.' (SWA document No. 7, 1973, p. 3.)

The CSIR, SWA at the NPL realized that it must support every such move. On 3 September 1973 the scientific, technical and auxiliary staff held a meeting to support the strike by the employees of the Shri Ram Centre for Industrial Research. It also passed a resolution supporting the Engineers and Doctors Council (ENDOC) and a few NPL scientists joined the ENDOC march to the Prime Minister's house on 21 September. (SWA document No. 7, 1973, p. 3.)

In this discussion we have attempted to analyse the nature of the industrial research laboratory and to show that industrial research arose as a result of the scientification of technology, which was followed in turn by the industrialization of science. The interaction between science and technology, university and factory, resulted in the creation of a new synthesis, a knowledge factory called the industrial research laboratory. Our discussion sought to unravel some of its contradictions by attempting to differentiate it from the university.

CHAPTER 6

INNOVATION

This chapter will attempt to examine the process of the transfer of technology from laboratory to industry. Since the transfer of technology takes place within a social framework, the process cannot be visualized as a purely technical one and the best way to understand it is through a case study of an actual transfer. Here more interest will be shown in the relations between laboratory and entrepreneur as two partners in the transfer process, and not so much in their internal dynamics as organizations. We propose to demonstrate how one laboratory unit through a learning process came to grips with the transfer problem and ultimately resolved it by bridging the various discontinuities between the laboratory and entrepreneur.

As pointed out earlier, the NPL was conceived as part of a network of research institutes responsible for taking science to industry. It was an infrastructure needed to improve existing technologies and to create new ones more appropriate for Indian industry. But the formal objectives of a laboratory do not always accord with informally existing trends of research, tempered by intellectual paradigms and professional ideologies. It is the interplay between the formal and the informal that has often constituted the stuff of sociology. The unfolding of the organizational dynamics which involved the working out of a relation between pure science, applied science and technology has already been described in the previous chapter. In so far as they affect the strategies of transfer, they will be discussed here.

The variegated activities associated with the transfer of technology can be summed up under the concept of an innovation chain. The innovation chain refers to the rationalized sequence of linkages between a scientific idea, its embodiment in a product, its commercialization, and its eventual impact on a wider society. For

analytical purposes, the chain is visualized in three stages, of invention, innovation, and diffusion, which are not essentially monotonic.

The invention stage is analytically the first. 'Invention involves origination.' (Parker, 1974, p. 14.) It requires the conception of a scientific idea and its technological possibilities. It not only includes the first thoughts about its embodiment in a scientific product or process, but its actual working out in a rudimentary form. This generally entails fundamental and applied research. Papers in journals are basic outputs at this stage. They entail a claim to knowledge of a new product or process, or a different way of producing an existing item.

Several writers on science and technology, following Schumpeter (1961), tend to emphasize the essential distinction between invention and innovation. The distinction recognizes the crucial social fact that not all scientific ideas that arise refer to a new idea or technique; innovation refers to the application of this idea or technique to the actual processes of production. The interface between the realms of innovation and invention brings us to the problem of the transfer of technology. Between the invention and the innovation, that is, (i) beyond the idea and its embodiment in a still untried product, and (ii) its actual introduction into the commercial sphere, lies a pre-testing stage. It involves the problem of commercial feasibility. Can the five gram sample created at the laboratory be produced in bulk and commercially? How does one convince the entrepreneur of this? This generally demands development work. One has to scale up the process optimized at the laboratory level and evaluate alternative methods of commercial production. This generally necessitates pilot plant activity. A pilot plant is a miniature factory, an attempt to stretch science on to the production line. Pilot plant activities represent a crucial link between the phases of invention and innovation and it is at this sensitive point that the problems of the transfer of technology from laboratory to factory emerge. We shall begin with the problem of invention, touching briefly upon the organizational dynamics which determined the strategies of technology transfer.

The NPL at its inception was an unequal blend of two cultures, the culture of the university with its emphasis on pure science, and that of the factory geared to production lines and profit. The majority of the top cadre in the laboratory were recruited from the

universities. These scientists were academics and brought with them the values of pure science. The value system of the scientific profession, which at the time of promotion preferred a paper in a journal to a patent relating to knowledge about technology, reinforced this. Against this dominant trend of pure science were two small groups, one working on carbon technology and the other on radio components. The leaders of the two groups wanted to develop an indigenous technology, and here we shall deal solely with the activities of the Radio Components Unit (R.C.U.).

As already noted in the previous chapter, the head of the R.C.U., T. V. Ramamurthy, was formerly technical director of National ECKO, a Tata concern, specializing in the manufacture of radios. The components unit started research on the problem of mica and ceramic capacitors with a view to understanding the scientific problems of ferro-electrics, and to develop a capacitor on a pilot plant scale. As long as the unit worked on the fundamental problems of ferro-electrics, there was no overt objection to its activities. Ramamurthy suggested that the laboratory make a thousand capacitors and see the user's reaction. The Director agreed, albeit reluctantly. Then the group decided to undertake even larger production, a step which worried the Director and the other scientists, for they felt that such efforts diluted the purity of scientific research. One distinguished member of the Executive Council accused Ramamurthy of transforming the NPL into a *karkhana* or factory. The opposition of pure scientists to any act which smacked of technology made Ramamurthy think seriously about the strategy for the transfer of technology to industry. To understand this we need some familiarity with the nature of the technology.

The technology of electronic ceramics can be visualized as a spectrum ranging from the simple to the complex. At the more primitive end we have the mica and ceramic capacitor branching out to the piezo electric ceramic and the 'entertainment' and 'professional' grade ferrite. It runs the entire technology spectrum from the radio capacitor, to the computer memory core.*

* A capacitor is a component in an electronic circuit which consists of a sandwich of two plates separated by an insulating material or dielectric. Its primary function is to store electrical energy when a voltage is applied to the plate. Piezo-electric ceramics convert mechanical to electrical energy. Ferrites are ceramics with magnetic properties used in radios, televisions and computers. A

ers (CEERI), various pressure and rate of flow measuring instruments, the photocopying machine (NPL) and the tractor (CMERI) are notable examples of product transfer.

The photocopying machine developed by NPL, and transferred to Advani-Oerlikon, is an outstanding example of product know-how where the licensee successfully marketed a product within a year of its development and that too at a price lower than that of the imported equipment. Models were tried out in record time, developed and licensed to four parties. The contracts were stiff and extremely safe. They specified that any new model that was significantly different from the original should be subjected to a fresh contract. There is usually a prototype of the machine available, which is handed over to the entrepreneur who can redesign the externals if necessary. He need not come back to the research and development unit. The relationship is thus a one-time affair, contractual and ultraspecific in obligation and usually based on lumpsum royalty. (Ramamurthy, interview, 1977.)

The nature of the relationship which processes know-how demands between laboratory and entrepreneur is essentially different. In all cases of process know-how there has to be a close and continuous exchange of information between the manufacturing unit and the R & D organization. The uncertainties inherent in process technology necessitate such a continuity. Process technology, even after pilot plant operation, requires a sizeable effort to make it commercially feasible. The crucial raw materials on which the technology is based might change in terms of grade. The manufacturing unit needs the help of the laboratory to work out the new process parameters. In development of this nature it is necessary to continue experiments on reasonably large batches to study the problems of variation in process parameters and also supply sizeable quantities for feedback information from field trials. For this the pilot plant becomes essential. When run on appropriate lines, with cost accounting, the pilot plant in a research laboratory provides the necessary infrastructures and data which will be useful for engineers in scaling up the plant to a commercially viable unit. In processing a material, as distinct from fabricating an instrument, the approach is a multi-disciplinary one. Processing involves—specially in the case of ceramics—physicists, ceramists, and mechanical and electrical engineers, all of whom have to co-operate to evolve a successful process. 'A lack of feedback results in mutual misunderstanding and the merits of the

basic process generally suffer.' (Ramamurthy, 1974, p. 4.) Thus process technology entails a relationship of continuous exchange between laboratory and entrepreneur. The obligations are diffuse, involving reciprocity, and, instead of lumpsum payment, the entrepreneur pays a running royalty.

In the following section, we shall consider case histories of various types of process know-how developed by the NPL and analyse the problems involved in the transfer of technology and the changes in strategy required to surmount these problems.

CASE 1

One of the first attempts to transfer technology from the laboratory to industry was with Indian Telephone Industries (ITI), a public sector undertaking to which the NPL passed on their processes for silver mica capacitors in August 1956. Ramamurthy, as head of the unit, decided that the best way to transfer technology was to ask ITI to send a small cadre of its workers to Delhi to be trained at the pilot plant. He emphasized that the conventional view of the transfer of technology as an exchange of formal information was incomplete. A technology has to be imbibed by participating in its actual operation. Consequently ITI sent twelve workers headed by a supervisor for training at the NPL. The workers were involved in the actual process of cutting, cleaning, punching, spraying and encapsulating the mica. The dozen strong cadre, along with the supervisor, ran the pilot plant for one year. During this time they produced 100,000 capacitors. These pieces were introduced into products produced by ITI and also tested at the Telecommunications Research Centre at Delhi. After a year, the ITI team went back to Bangalore and commenced production.

ITI produced 36.7 million silver mica capacitors valued at Rs 45 lakhs and used them extensively in their professional grade equipment. They did not supply or sell to outside parties or export it, utilizing these capacitors solely for their own equipment. This did not fully meet one of the main purposes of indigenous technology, which was to stop imports. Consequently, the NPL, through the NRDC, licensed the firm of Manilal Mohan Lal for the production of mica capacitors. Manilal Mohan Lal began production in 1960 and by 1964 had reached 10,000 silvered blades

a day. In this case licensing was on an exclusive basis, which created problems for the development of indigenous technology. To understand this specific case, one has to understand the background of the problem of mica in India.

Mica is one of India's major export earners. The mineral is generally exported in bulk and in an unprocessed form and fabricated into components in Europe and America. Given the nascent development of the electrical and electronic industry, mica remained an export-oriented industry in India. For example, in 1960 India was exporting 2,500 tonnes of raw block and film mica which was used for valves, mica capacitors and other components. The nascent electrical and electronic industry was utilizing a mere two tonnes. Scientists in the NPL argued that, instead of exporting raw mica, India processed it into films, valves and electrode supports, the country would be able to earn a higher price from exports. The mica export council indicated an interest in the problems of indigenous fabrication but the exclusive agreement with Manilal Mohan Lal prevented the NPL from pursuing the matter further with any other party. The constraints of exclusive licensing forced the NPL to drop any plans for the development of an export-oriented mica technology. (Ramamurthy, letter, No. 3.)

CASE II

The second experiment, also on the basis of exclusive licensing, was with Bharat Electronics Limited (BEL) for the manufacture of ceramic capacitors. The NPL developed a process for the manufacture of ceramic capacitors, which commenced in 1956, and successfully ran a pilot plant for three years producing and selling 5 million capacitors to the radio industry. BEL evinced a keen interest in taking over the process and, although negotiations with a private firm (REMCO), had proceeded to an advanced stage, it was finally decided that BEL, being a public sector undertaking, should be given the license in the national interest. The negotiations carried on for two and a half years.

This time the NPL introduced a slight variation in the transfer process. It decided to transfer some of its own key personnel to BEL to smoothen the process of technology absorption. Three technicians from the NPL, who headed crucial aspects of materials processing, were absorbed by the licensee to ensure the smooth

flow of technology absorption. In the first stage the pilot plant at the NPL was run by BEL officers under the guidance of the NPL. In the second stage, when BEL had got all their imported and locally obtained machines installed, the entire process was transferred to the factory along with the three key technicians. During Stage I, the pilot plant at the NPL was BEL controlled. BEL provided all the salaries and all the profits and materials accrued to BEL. Their cost accountant was also attached to the cell as a controlling officer.

BEL operated the pilot plant at the NPL from November 1960 to October 1962. By January 1962, the first phase of production was completely transferred to BEL. At this stage raw materials processing was done at the NPL, the semi-processed tablets being sent to BEL for further fabrication. The second stage of the process was completed by October 1962. This two-step transfer was deemed necessary in order to maintain a continuous supply of condensers to the radio industry.

The transfer was, however, beset with preliminary difficulties. BEL had initially promised to start production by June 1962. In June 1962 the Managing Director of BEL requested the NPL to postpone the complete transfer for a three month period, thanks to the delay in the arrival of imported equipment (letter, No. 1). The Deputy-Director in charge of the NPL was reluctant to make any concessions not visualized in the contract. He feared that the NPL's preoccupation with capacitor production would retard its programme of research and development. In fact, he warned BEL that he would under no conditions continue the pilot plant at the NPL beyond the extension period of three months. He added in a letter dated 28 July 1962 that with the completion of the work on the capacitor, the NPL would be fulfilling the terms of the agreement concerning ceramic capacitors. Fortunately BEL was able to begin production by October 1962.

The relation between the laboratory and the entrepreneur does not however end with the guillotine-edged that the Deputy-Director of the NPL seemed to visualize. As soon as BEL started production operations, the relation between the laboratory and entrepreneur stepped beyond the contract and entered the realms of exchange. It is the problem of continuity and reciprocity in the relationship between laboratory and factory that we shall proceed to examine. We will have to take into account (i) the general

environment of entrepreneurship, (ii) research policy, and (iii) the mutual role-expectations between laboratory and entrepreneur.

One of the first problems necessitating a continuous interaction between laboratory and entrepreneur was the problem of raw materials. Most of the raw materials used at the pilot plant at the NPL were standardized ones conforming to the British Pharmacopoeia. The varying qualities of certain other raw materials supplied in bulk necessitated constant manipulation of process parameters (Ramamurthy, Bell Capacitors Report, 1962). This required a close and constant interaction between laboratory and production unit.

The second problem which required close co-operation was the necessity of automation. The know-how for ceramic capacitors was based on a process utilizing manual labour. The laboratory realized that though such a process might be adequate in the early stages of indigenous development, a certain degree of automation was necessary with an increase in the scale of production. Ramamurthy went down to BEL in April and July 1962 to make a comprehensive survey of production operations. He found it possible to improve the efficiency of production at each stage through simple time and motion studies. He also planned the introduction of semi-automatic machines with the aid of which daily production per worker would increase from 1,000 to 3,000. Detailed drawings, sketches and plans were provided by the NPL scientists to step up production by semi-automation.

Ramamurthy realized as early as 1962 that the requirements of semi-automation and the problem of raw material, and research into its improvement and standardization, required that a development-cum-testing laboratory be attached to the capacitors section at BEL. This development laboratory was not set up, nor was the NPL involved on a continuous basis in anticipating the later problems of the technology that was transferred to BEL.

The BEL management was not enamoured of the possibilities of semi-automation. (Proceedings, BEL Board, 60th meeting.) It estimated that the demand for ceramic capacitors by the Fourth Plan would be 35 million and contended that the processes based on NPL know-how would not allow the rapid increase in production needed to match this anticipated increase in demand. The know-how from the NPL only covered the production of disc-type capacitors and not the production of 'plaquettes'

required in large quantities by the transistor radio industry. Since the know-how for complete automation was not available in the country, BEL decided to negotiate with the French multinational, CSF. The Managing Director of BEL pointed out that 'the addition of automatic machinery, the production techniques, process controls, know-how etc. from LCC (a CSF subsidiary) would be highly advantageous to BEL' and added, 'the information available with and furnished by the NRDC would not help BEL maximize and diversify output and lower costs.' (Proceedings, BEL Board, 60th meeting, p. 1.)

The BEL management further cited the case of Philips, India, who were licensed to produce ceramic capacitors after NPL had licensed BEL through the NRDC. To compete in both volume and cost of production with Philips, who were using fully automated equipment, BEL insisted on complete automation.

In its discussions with BEL, the NPL argued that the move to total automation was not warranted. The NPL contended that the demands of the radio industry were small and varied, and challenged the reliability of the forecasted demand. Under these conditions it felt semi-automation was a more sensible course to adopt and would help production where it seriously affected quality. The NPL representative held that the choice of a particular technology had to be considered in a wider perspective. In his memorandum on this subject to the Director-General of the CSIR, Ramamurthy stated, 'with our large population and increasing unemployment, are we right in discarding methods of manual production wholly in preference to a fully automated plant, where we will require assembly workers?' (Memorandum to defence adviser, 1964, p. 1.)

The development of an indigenous technology had to combine as harmoniously as possible two difficult requirements which often pull in opposite directions: the need for efficiency and productivity and the need to prevent unemployment. In a letter to the defence adviser who was mediating in the debate, the NPL representative held that there were many ways of entering into agreements for know-how with foreign firms other than that envisaged. He argued that there were several firms in Europe and America who were prepared for commissions of 7.5 per cent to 10 per cent to design and manufacture machines for any product and any quantity required. There would not be the need to pay continuing royalties

to these firms once the machines were manufactured and installed. (Memorandum to defence adviser, 1964, p. 4.) These machinery manufactures would be prepared to give advice on other matters, too. Ramamurthy cited the example of the extruding machine which BEL had imported from Germany. Here the manufacturers were ready to advise even on the finer points of the process when BEL sent them material to be tested on the machine. BEL, the NPL representative argued, was seeking the typical bureaucrat's umbilical chord to safety, a foreign collaboration. BEL nevertheless entered into an agreement with CSF. It is reported that the fee charged was Rs 28 lakhs (Ramamurthy, 1973, p. 16). The only equipment BEL got from the foreign collaborators was a conveyor-belt system automatic equipment, and training for its engineers. All the other equipment which had earlier been acquired by BEL on the NPL's advice was still being used in 1980.

In addition, BEL chose to abandon tried and tested indigenous raw materials and decided to import them. The irony was that one of the raw materials, titanium dioxide made by Travancore Products, Kerala, and exported to France, came back at literally ten times the price. Furthermore, the ceramic capacitors made by BEL and based on NPL know-how were sent to LCC (the subsidiary of CSF) who were also making ceramic capacitors; LCC reported that the NPL had successfully overcome bottlenecks in developing an indigenous process for the manufacture of ceramic capacitors. (Schlumberger report, 1956.) It only required large-scale production and the firms themselves advised that this could be done by the BEL engineers. But when the BEL management chose to go in for total automation, CSF insisted on the import of raw materials. Finally, BEL's argument that automation would bring down costs became only partly valid. The original capacitor which cost 25 paise cost 23.3 paise in 1980.

In 1966 the NPL submitted a note to the Director-General of the CSIR which asserted that since BEL was seriously proposing to enter into a collaboration agreement with CSF, the NPL should be permitted to license other manufacturers. The note pointed out that the NPL had received a large number of inquiries from industrialists and had not been able to entertain these requests as the licensing agreement with BEL was an exclusive one. The note added that, compared to BEL, small-scale industrialists may be in a position to produce ceramic capacitors at more competitive rates

because of smaller overheads. On 23 June 1966 (Letter No. 5, 1966) NRDC requested BEL to release the NPL from the exclusivity clause. BEL was reluctant in the initial stages (Letter, No. 4, 1966) but decided to release the NPL when the latter agreed to forgo its royalty for the remaining period of the license. As soon as the agreement was amended, as many as seven parties took licenses for ceramic capacitors. One of them, Micro Ceramics Limited, which obtained a license in May 1969, has reached a production capacity of 10 million capacitors by 1972.

A fuller understanding of the BEL/NPL case demands that we examine the existing expectations between laboratory and entrepreneur in greater detail. In his report to Dr Bhagvantam, Scientific Adviser to the Ministry of Defence, the Managing Director of BEL who asked for a critical appraisal of the BEL/NPL relationship, remarked that the know-how obtained from the NPL was not adequately developed for industrial exploitation (letter, No. 2, 1963). The norms of judgement, he contended, were the norms of the market which demanded comparability in quality, finish, and perhaps cost, with imported items. (Report on exploitation of laboratory know-how, 1963, p. 1.) The Managing Director contended that the processes from the NPL did not lend themselves to automatic production on a mass scale. He also faulted the NPL process on other grounds. First, the specifications of raw materials were not fully worked out prior to the transfer. Second, there was a faulty choice of equipment. The furnace that the NPL recommended and used at the pilot plant was not suitable for large-scale production. (Report, 1963, p. 4.) Finally, information regarding wastage was not available. He felt the pilot plant was not run on industrial lines. Ramamurthy accepted that the difficulties experienced by BEL were genuine, but the conception of the laboratory production unit was not easily acceptable. (Ramamurthy, letter No. 3, 1964.) 'The suggestion that the pilot plant should equip itself with the most modern machinery including an automatic plant for production will practically mean the establishment of a factory with consequent heavy expenditure involved in plant and machinery and is likely to be a permanent liability.' (Ramamurthy, letter, No. 3, 1964.)

The BEL Report exaggerated the factory element of the laboratory and misunderstood the role of the pilot plant in technology transfer. As Ramamurthy visualized it, the rela-

tionship between licensee and laboratory is one of continuity, given the imperfection of the technology. Ramamurthy thus conceived of the whole dynamics of technology transfer as a learning process. If industrial processes developed by national laboratories are to be successfully converted through organized ventures, it will be invidious to compare indigenous know-how with what a firm gets by way of expert advice from a foreign firm with an established reputation.

The expectations of BEL and its complaints to such government committees as the Kane Commission on Pilot Plant raised a series of crucial questions regarding the role of the industrial research laboratory in the development of indigenous technology. (Ramamurthy, note to DGSIR, 1964, p. 3.) First, up to what stage should the laboratory go in developing a process for the manufacture of an item. Is it necessary for the laboratory to invest large sums of money in automatizing a process which has been proved viable on the pilot plant basis? Secondly, should not factories, particularly those in the public sector, with fairly large resources of engineers and money, take some responsibility and initiative in gradually building up production capacity by the introduction of semi-automatic machines? Thirdly, should process know-how be licensed exclusively? Ramamurthy in his letter added that these questions demanded immediate policy decisions. He added,

The Indian Telephone Industries had written on 22 August that they would like to discuss with us some of the points connected with the manufacture of soft ferrites in ITI based on the NPL's developmental work. This again poses the very same problem as in the case of BEL, and earlier with ITI in silver mica capacitors, as to what extent we should develop the process in the pilot plant before passing on the 'know-how'. An identical problem as in the case of BEL will arise if we pass on the know-how at a stage when we have yet to work the process with semi-automatic machines, or automatic machines which have to be imported. Or else we have to get the assistance of Industrial consultants to fabricate the equipment.

A policy decision on the basic questions posed is necessary for fruitful discussions with ITI. They are critical about our processes in regard to silver mica capacitors and we will have to guard against a similar situation arising in the case of ferrites. (Ramamurthy, note to DGSIR, 1964, p. 4).

The next two case histories reveal the laboratory's response to these problems.

CASE III

The NPL undertook a project on ferrites in 1961 and commenced systematic work on the development of ferrites of various grades for the electronics industry. By the time the NPL had developed the process, the CSIR had decided that the laboratory should no longer transfer the process on an exclusive basis. A single licensee is generally unable to meet the entire demand of the country. The NPL licensed its process on entertainment grade ferrites to two firms, Morris Electronics and Semi-Conductors Limited. But the policy of multiple licensing soon created problems for the laboratory. Since the laboratory was issuing licences to other parties also, the entrepreneur did not permit scientists to visit his factory, because he was afraid that they would pass on information to his competitors. Assurances by the scientist that he would not do so were of no avail. Another source of tension is the fact that the research institute, which continues to work in the same field, is seen by the licensee as a competitor. This happens especially in the case of smaller concerns. Invariably they want the NPL to put a stop to all further developmental activity, which is what happened in the case of NPL-4, an entertainment grade ferrite. Morris Electronics, the bigger firm, which was eventually responsible for putting ferrites production on its feet, had no objections. But Semi-Conductors thought that the NPL pilot plant was competing with them and wanted the plant stopped. This is why the NPL had to stop the further development of NPL-4.

In the case of NPL-5, another entertainment grade ferrite, the NPL refused to stop its pilot plant activities even though the entrepreneur objected. Consequently, the NPL was able to reduce its costs without any further sacrifice in quality.

CASE IV

In August 1963 the NPL learnt that negotiations were underway between ITI and Philips for the manufacture of ferrites. Philips had been invited to offer know-how, both for professional grade ferrites required by ITI for their telecommunication equipment and for entertainment grade ferrites required by the radio industry. (Estimates Report, 1966, p. 51.) The NPL protested to the authorities concerned, arguing that since entertainment grade

ferrites had already been successfully developed by it, Philips should confine themselves to professional ferrites alone. The Industries Minister accepted the stipulation as a condition for ITI's collaboration with Philips. Philips, however, refused to accept the condition, contending that know-how for professional ferrites automatically involved know-how for entertainment ferrites and, therefore, both should be paid for. (Estimates Report, 1966, p. 55.)

It is worthwhile to quote Ramamurthy in detail here:

The ferro-magnetic area is based on the same ceramic technology as the ferroelectric. When the NPL was surveying the ferrite area we found that the more sophisticated requirements were those of ITI. But their value (at that time) represented a mere Rs 10 lakhs. But the antenna rods and coil cores required for the radio industry were estimated at ten times the amount. Thus the NPL decided to concentrate on the one crore bit first. We got into antenna rod production. Here we found that nickel was being imported, and substituted it with manganese. We released the process to Morris Electronics and Semi-Conductors and today the entire requirements are indigenously met.

Then we moved into professional ferrites. When Philips found out about this they moved into action. Ferro-magnetism was the unique contribution of Philips to electronics. Their scientists, Snoek in particular, have done intensive laboratory work on it. Philips were hurt to find out that indigenous manufacture had been set up with no Philips finger in the pie, as either licensee or collaborator. They offered an entire production unit to ITI on ridiculous terms—an entire plant for Rs 5 lakhs, machinery and all, and everybody swallowed it. Philips on ferrites was gospel. It was a name to conjure with. Philips have been trying to enter the field of electronics. Under this guise they will move to X-ray machines, diathermy, etc. I think the Directorate-General for Technical Development (DGTD) is clearing it. Philips have promised to give a grant of Rs 50,000 to any laboratory provided it can match it with an equal sum. People fall for this kind of philanthropy. It is time they realize that multinationals are not Mother Teresas.

However, when Philips found they were being restricted to professional ferrites alone, they refused to collaborate, unless offered both. All the time they had their eyes on the bigger, one crore project. They claimed that professional grade ferrites and entertainment grade ferrites were the same animal, not two different ones. By this time I was in a hospital with a heart attack. Hussain Zaheer had become the new Director-General of the CSIR. Initially he agreed to the Philips proposal. I wrote desperate letters from the hospital. Zaheer realized that Philips were holding a pistol to our heads with their all or nothing proposal. There was a certain

magnanimity about the man. Thanks to Zaheer, we could hold Philips at bay. (Interview, Ramamurthy, 1976.)

In 1963, the NPL wrote to ITI offering to undertake the development of ferrites of the requisite quality required by ITI. The ITI were, however, reluctant to accept the NPL process, contending that their experience in the NPL process for silver mica capacitors had not been a happy one. They also emphasized that there was a gulf between the professional grade ferrites required by the ITI and the entertainment grade ferrites which the radio industry was manufacturing under a license from the NPL. (Estimates Report, 1966, p. 51.) In a statement before the Estimates Committee, the Secretary of the Ministry of Communication explained ITI's stand as follows: 'There are thousands of types of ferrites. We gave our requirements. After that for a long time we did not hear anything further. The NPL had promised to send us samples of ferrites they had produced. Those samples were not sent as far as we know till 1964. And we did not receive the details as to whether the ferrites would be in accordance with the specification required. In any case we are not interested in the entertainment type of ferrites. We are more interested in the professional type, that is hard ferrites.' (Estimates Report, 1966, p. 53.) The Secretary added that it was not possible to design production equipment around an unknown factor.

The Hussain Zaheer, presenting the CSIR side of the story before the Committee explained:

Right in the beginning of 1964 we had a prolonged session with Dr Ramamurthy, Mr Ranganathan (ITI), and Mr Vasudevan (ITI) over these problems. At this stage we were ready with the entertainment type of ferrites and not with the professional type. The negotiations with Philips were also going on. They insisted they should have both or none. . . . In April 1965, the NPL and ITI held another meeting. At this meeting the ITI officials argued that the NPL was not yet ready with the ferrites and since ITI was losing considerable foreign exchange due to the delay, the NPL might as well allow Philips the license for both types of ferrites. Later on my colleagues at the NPL told me that they were actually ready with professional ferrites also and therefore requested that no agreement with Philips should be entered into. I took some time to assure myself of the fact. In the mean while we had the testing done by the LRDE. Then in the middle of December 1965 I wrote to Ranganathan saying we had now reached a stage where no further negotiations with Philips should be carried on. (Estimates Report, 1966, p. 55.)

At a meeting in March 1966 between the Director-General of the CSIR and the Secretary of Communications it was decided that, since negotiations with Philips for the making of professional ferrites only had fallen through, the NPL should undertake their development. (Estimates Report, Appendix 5.) ITI gave specifications for the latest type of ferrites which Philips had introduced into the 1966 market. In response, the NPL began acquiring equipment, dies and tools, simultaneously initiating a programme of laboratory studies on ferrites. After several initial difficulties in meeting the extremely stringent specifications laid down by ITI, the NPL succeeded in producing samples laid down by the ITI specifications of 1966. In the meantime, however, ITI had revised its temperature-range requirement in conformity with the specifications of the new product range that Philips had introduced into the market in 1969. (Ramamurthy, 1973, pp. xxi-v.)

The progress of work at the NPL in producing ferrite samples was evaluated by high-level committees in 1969 and 1970 and decisions taken at a meeting on 24 April 1970 were crucial. At this meeting the NPL was authorized to set up a production facility for the manufacture of professional grade ferrites. The meeting resolved that: (i) in view of the fact that the NPL had already achieved a good measure of success in the manufacture of samples of professional ferrites broadly conforming to the specifications given by ITI, its ferrites should be accepted by ITI; (ii) the NPL should go ahead with the project on a top-priority basis, and perfect samples so that they reach the specification requirements in all respects; (iii) the first lot of 200 kg of ferrites must be supplied by the NPL to the ITI by 15 August 1970.

A further meeting was convened in November 1970 by the Minister of Information. The Committee noted that the NPL was unable to undertake production of high permeability professional ferrites, as promised, for lack of raw materials of adequate purity. It resolved that the NPL would be given three years to set up a production unit to meet ITI's requirements. On 8 August 1972, the President of the CSIR issued a directive that a separate unit be created specially to run a production plant and meet ITI's requirements. The mandate declared that this ferrite unit be separated from the normal activities of the NPL and be placed under the Committee for the Development and Production of Electronic Components. The President also observed that it was

necessary to facilitate a smooth interfacing between the ferrite plant at the NPL and a proposed public sector company at Naraina in Delhi.

Meanwhile, a new agency was entering the scene. The Electronics Commission, which had been set up to rationalize the variegated research and production activities in electronics, constituted a committee to investigate the whole problem of the indigenous development of ferrites. The Committee, which was established in January 1972, came up with its final draft in January 1973. It was signed by its members and ready for presentation. Oddly enough, another meeting was held again on 9 February 1973, when the paragraphs concerning professional grade ferrites were altered. (Ramamurthy, 1973, p. 17.) Part of the controversy was a result of the minute of dissent submitted by T. V. Ramamurthy, the NPL representative, who differed from the schedule of production drawn up by the panel. The Committee held that 'developmental work was carried out along empirical lines and on a batch to batch basis with the aim of tackling and adjusting parameters, one at a time.' (IPAG Report, 1973, p. 62.) It stated that 'extended development work will be needed to establish a continuous process and to bring all parameters within day-to-day control of production'. The Committee held that the NPL would not be able to supply the bulk quantities required by the end of 1976. It therefore allowed ITI to finalize its package deal with a foreign collaborator, Siemens, which guaranteed production of the pot crores of the required specification by 1975. The 'committee's panel report, to which the NPL representative had objected, was however, submitted to the Electronics Commission without his dissenting note. (Ramamurthy, 1973, p. 18.) But the NPL representative refused to concede defeat.

Ramamurthy contacted Dr. M. G. K. Menon, Chairman of the Electronics Commission and gave him a copy of the dissenting note, pointing out the various lacunae in the Report. Menon informed the Commission that, as far as telecommunication ferrites were concerned, the Commission need not come to any decision. (Ramamurthy, 1973, p. 18.) On 16 July 1973, the Director of the NPL received a letter from ITI stating that they were finalizing collaborative agreements for a package deal. What becomes clear from all this is that ITI were continuously carrying on negotiations with foreign firms. As Ramamurthy remarked:

At the last meeting of the panel on ferrites, they came up with the proposition saying they had a complete project report from Siemens, whereby with an investment of Rs 48 lakhs in foreign exchange, they will be able to set up production of telecommunication ferrites and TV components. Their representatives produced two bulky volumes at the meeting and obviously this detailed project could not have been drawn up overnight. Given a co-operative attitude by ITI right from the start, the NPL scientists would have been able to solve the problem much earlier and generally supplied the quantities in stages, and thus make the country self reliant in technology. (Interview, Ramamurthy, 1977.)

But there was still hope for the NPL. Ramamurthy tried to infuse new life into the CSIR mandate of 1972, which had called for the creation of separate production unit to meet indigenous ferrite requirements. However, the authorities now felt that the Electronics Commission should approve of this move; strangely the Electronics Commission appears to have dragged its feet for a year and a half in reply to the CSIR. As Ramamurthy remarked: 'I had to start nibbling at all these people again. I told the Minister of Science, Mr Subramanian, that things would not get going unless he asked Menon for an explanation regarding the delay, insisting he should give a decision one way or the other.' (Interview, Ramamurthy, 1977.) A Committee was soon established with Professor E. C. Subba Rao of IIT, Kanpur, as Chairman. The Committee endorsed the feasibility of the NPL project.

Mean while, before the new company, Central Electronics Limited, was established, once the Electronics Commission had approved of the proposal, the CSIR had authorized Rs 38 lakhs for the creation of a separate Electronics Components Unit. This production unit was eventually to merge into the proposed public sector company. 'The Minister of Science, Mr Subramanian, was so enthusiastic about the whole idea that he felt that the production complex should be a public limited company under the Ministry of Science and Technology. This was something unique as most public sector undertakings were under the Ministry of Industry. This again required cabinet permission and was obtained.' (Interview, Ramamurthy, 1977.)

Subramanian then convened a meeting with Dr Nayudamma, the new Director-General of CSIR and M. G. K. Menon. Menon endorsed the idea: The prospect of a small enterprise managed by scientists evoked, in a modest way, Boston's fabulous

Route 128. The Minister, however, added an important modification. He felt that, while the proposed unit was a take-off from the NPL, it should not be tied down to the latter alone. Its scope should be enlarged to embrace all R and D organizations in electronics, for once the proposed unit developed the expertise, the laboratories need not be harrassed by the problem of pilot plants. CEL would take them from the laboratory stage and develop them further. CEL is today a living public sector entity and the laboratory had become the entrepreneur.

Ramamurthy remarked that

the coming of CEL was inevitable. Blackett sensed it over a decade ago. The idea of a production complex was first suggested by P. M. S. Blackett. Nehru invited Blackett in 1963 to go into the working of the NPL. Blackett was extremely impressed with the Radio Components Unit. He felt that the Unit had all the makings of a full-fledged commercial enterprise. Blackett did not approve of the idea of passing on technology to the entrepreneur. Probably sensing the entrepreneurial atmosphere in the country, he suggested we produce it ourselves. (Blackett report, 1973, p. 2.)

Looking back, he was right. Maybe that way we would have avoided the criticisms, the half truths of the Kane Commission Report. Instead of running across the technology chain from mica capacitors through ceramic capacitors to ferrites, we could have stuck to one item and done well. Maybe we should have concentrated more on production. If we had stuck to ferrites, we could have reached production requirements in no time. You see we had process know-how. If we had gone into production ourselves we would have gradually acquired the engineering know-how too. That is where the foreign firms tend to score over us. They provide turnkey technology. We pass our process know-how after having worked with it for a year. They not only have process know-how, but engineering know-how too, experience in working with the technology for years. But there was a certain consistency in our approach too. We acquired expertise in a complete technology spectrum, ceramics. It is just that the continuity and reciprocity of relationships between laboratory and entrepreneur, that process know-how required up to the development stage, never come true. (Interview, Ramamurthy, 1976.)

A case in point is that of professional ferrites. The ITI reports themselves admitted that deviations from the specifications of the NPL pot cores were only mechanical and not basic to the material. (Ramamurthy, 1973.) Given a collaborative effort between the processing knowledge gained by the NPL scientists and the

experience of ITI in the use and application of ferrites, it was not beyond the competence of ITI and the NPL to solve problems quickly had they worked together. This would have ensured that the research and development that had gone into the project would not become what the Kane Commission was to call 'an infructuous exercise in development'. It is precisely the necessity of the continuity of the innovation chain that Blackett emphasized.

Blackett emphasized the necessity of conceptualizing the innovation chain as a whole. 'It is extremely important to consider the whole chain of activities—research, development, design, production, sales and post-sales service as a single whole. This is the process of successful innovation. The first stages of R and D consume wealth—only the later stages of production and sales produce wealth. (Blackett, 1973, p. 13.) Blackett remarked that it is not sensible to embark on R and D programmes unless it is highly probable that the later stages of the innovation chain will be looked after. 'If the R and D is not exploited by industry the community is poorer by the cost of R and D. But the problem of the continuity of the innovation chain is a complex one in India, where little research and development is done by firms either public or private, and nearly all in government research establishments. This being so, it is quite vital that some means be found to take care of the later stages of the innovation chain. It is not sufficient to embark on an R and D project and hawk it around to an unsympathetic industry. (Blackett, 1973, p. 15.) This risk of discontinuity eventually forced the NPL to become its own entrepreneur, to ensure a genuine relationship of exchange between laboratory and production unit.

We have completed our description of the NPL's attempts to develop an indigenous technology for electronic components. The electronics components experiment was chosen because it is an outstanding example of limited success and reveals both the constraints and the possibilities of the present system. What can we abstract from this study about the problem of indigenous technology in general?

One startling fact is the utter lack of consensus regarding science policy for developing indigenous technology. More particularly, there seems to be no clear-cut conception at the policy level of the role of the industrial research laboratory in the development of indigenous technology. The main source of confusion centres

around pilot plant operations. Dr Amarjeet Singh, the Director of the CEERI, Pilani, remarked at a National Conference of Electronics (which included policy-makers) that comments at the conference had equally emphasized that laboratories must and must not have pilot plants (Singh, 1971, p. 239); it was not clear whether the laboratory should work on the day-to-day problems of production or confine itself to basic research. This confusion is found at three levels—the laboratory, the entrepreneurial and wider policy levels. Even after the Blackett Report of 1963, many scientists had no clear understanding of the role of the laboratory and felt that once they had produced a successful sample on the laboratory bench, their job was over. They failed to realize that one prototype solves the problem only partially. It has to be produced in numbers and research and development cannot be enacted solely on the laboratory bench. But many scientists felt that the problem of ensuring repeatability on a mass scale was not the task of the laboratory and were hostile to pilot plant operations. This confusion was also felt by the entrepreneur, who failed to conceive of the pilot plant as a half-way house between theoretical possibility and commercial feasibility. For example, the BEL management seemed to over-emphasize the pilot plant's potential as a factory. Their opinion is in stark contrast to that of the scientists, who felt that mundane production problems were not their responsibility.

The Kane Commission instituted by the CSIR to go into the problem of pilot plants merely clouded the issue further. It referred to the ceramic capacitors plant at the NPL as an outstanding example of the 'futility of rediscovery'. With the mentality of a cost-benefit ledger, the Commission suggested that it would be more reasonable in terms of efficiency and foreign exchange to buy technology rather than duplicate it. It took a facile attitude to the problems of technology absorption and failed to visualize the innovation chain as a long-learning process which has to be traversed before obtaining turnkey technology. The adaptation of foreign technology and its further development requires a prior replication at the pilot plant stage. However, the Kane Commission in its recommendations proscribed the use of pilot plants for this very purpose.

This confusion about pilot plants in industrial research brings us to the wider conception of innovation itself. The concept of the

innovation chain visualizes the whole gamut of activities, from a scientific idea to actual commercialization, as a fluid, rationalized set of movements. Conceptualization alone is not enough. One of the basic problems is to translate it into a series of institutional structures incorporating the image of innovation as an integrated whole. For example, there is the necessity of seeing continuous information flow between the laboratory and production unit. The National Research Development Corporation, which mediates between the laboratory and the entrepreneur, hardly bothers to insist on reciprocal information beyond the first contract. Coping with the later problems of developing technology depends entirely on the personal relations between laboratory scientists and production staff.

There is a second and equally crucial problem. The innovation chain is often visualized as a unidirectional flow of information from the laboratory to the production unit and the critical importance of information coming back from the production unit to the laboratory is not well understood. This is the crucial element of feedback. It is not just a case of invention reacting on innovation, but the problem of innovation reacting and sustaining further invention. The absence of reciprocal information in the BEL and ITI cases ultimately led to the breakdown of the transfer of technology from the NPL to these units.

We must also try to understand the difference between the rationalities employed by the innovating scientists who is developing indigenous technology and the production man. Whereas the entrepreneur looks at technology merely as one factor of production, an input into a wider system, scientists like Ramamurthy visualize technology as embedded within a system of social relationships. Scientists view technology as ideology and visualize the choice and development of indigenous technology in terms of wider social and political considerations. The first view, which is the managerial or technical one, is concerned merely with considerations of the market, of short run profit and efficiency. The Managing Director of BEL, while advocating mechanization and the choice of CSF technology, remarked that his criterion for the evaluation of indigenous technology is market compatibility. Is indigenously developed technology comparable with imported technology in terms of finish and cost? The scientists of RCU tried to conceive of mechanisation in terms of wider social costs like unemployment.

The favourite argument of technical rationality against the development of indigenous technology is the buying-time argument. The general contention is that the import of know-how reduces our technological lag and is more efficient. This bounded rationality has to be confronted with a wider social and political rationality. Ashok Parthasarathi, one of the more sociologically sensitive electronics experts, cites the example of transistors and integrated circuits as two generations of the same technology to repudiate the above argument of technical rationality. (Parthasarathi, 1971, p. 56.) He remarks,

At a certain point of time, a number of companies imported know-how for the manufacture of transistors. The collaboration agreements are of a five-year duration. We are told the object of entering into such an agreement is to save us the time required to develop transistor production and enable us to go straight to the production stage. The implication here is that within five years the companies that import the know-how will be able to manufacture transistors on their own and will not need collaboration thereafter. The argument, though appealing, is facile. It presupposes (i) that the entrepreneur has committed substantial resources to development and (ii) that these resources are committed not only to design and development but to the whole of the innovation chain. What actually happens is quite different. Time after time, just as the collaboration agreement comes to an end, the company shifts their attention to the next generation of products. They argue that after five years of their transistor licences massive obsolescence has taken place and that India should not be allowed to lag behind in the technology race and therefore they should be allowed to import components. The plea of course is the same, to buy time. What it actually amounts to is a process of import, generation after generation.

Parthasarathi also raises another basic issue. He observes that the transfer of technology between foreign firms and local units occurs within a political structure of dominance and compliance. The local units are not allowed to experiment with the process or substitute raw materials as the BEL case testifies. The foreign firms discourage laboratories from investigating the process. All this tends to perpetuate the existing relationship of dependence. However, he feels that the transfer of technology between the CSIR laboratories and local production units can be one of equal exchange, through which in the future the relationship of servility to foreign technology can be changed.

CHAPTER 7

DIFFUSION—THE LABORATORY AND
THE MARKET

In this chapter we shall discuss the role of the industrial research laboratory in the diffusion process. The innovation chain can be visualized as an information system demanding translation between the various subsystems. The disjunction between pure science and applied science, or between invention and innovation gives rise to the crucial problem of transmitting and translating scientific information from one subsystem to another. This metaphor of the innovation chain as an information system is particularly appropriate in understanding the part played by the industrial research laboratory in the diffusion process. Research management studies generally tend to restrict themselves to the interface between invention and innovation. But scientists in the laboratory argue that it is only those active in industrial research who can monitor certain trends in research and decipher their implications for existing markets. They hold that in a marketing agency, or even a factory involved in routine production, such scientific problems might appear as so much noise; it is only the scientists who can anticipate the warning signals inherent in new research trends. This role is particularly crucial within the context of a developing society, which is all too often restricted to an economy of primary products. It was precisely this enforced obsolescence inherent in industrial research, especially in synthetic chemistry, that led the scientists of the *Science and Culture* network to demand an infrastructure of laboratories to counteract it. Thus, Kanailal Roy even attempted to devise indicators which would monitor trends in research in synthetic resins and plastics to anticipate their market implications for products like lac and jute. As Roy seemed to implicitly suggest, and as scientists at the NPL explicitly emphasized, the conventional market models of diffu-

sion were inadequate, given their managerial emphasis, they appeared to ignore the wider dynamics of development and under-development and fail to recognize the other face of market diffusion—obsolescence.

The following sections will describe two case histories: one of raw material mica, and the other of a manufactured product, the radio, within the framework of a centre-periphery model. In the first case, the centre will be an industrial metropolis, and the satellite a primary-product society. In the second study the centre will be the town and the periphery, the countryside. In both studies we shall attempt to emphasize the role of the industrial research laboratory in the protection and creation of markets.

I

In August 1972 the Operations Research Group [ORG], a consultancy organization owned by the Sarabhai conglomerate, published a three-volume report on the export potential of mica. The report stated that 'India is the largest producer of mica of high commercial quality and meets about 80 per cent of the world requirement of strategic mica.' (ORG, 1972, p. 1.) The mica industry, it pointed out, was entirely export oriented and export earnings from mica placed it among the first twenty export commodities of India. The report emphasized that, while India enjoyed a virtual monopoly in the mica market, exports of mica had showed no perceptible growth since 1960–1. In fact, since 1966–7 exports had declined in terms of total tonnage. The ORG presented a detailed report of the mica industry but failed to systematically analyse the role of the industrial research laboratory in this process. The following section will attempt succinctly to describe the nature of the mineral and its extraction and to emphasize why a particular international division of labour arose. It will then link the mine and the laboratory within a single product cycle, analysing the destruction of the market for mica.

II

While mica is a common constituent of most igneous rocks, commercially workable quantities of mica exist in only a few restricted areas in India, Brazil, South Africa and the USA. Mica is probably the most versatile mineral known in view of its high

dielectric strength, extreme resistance to high temperatures, chemical inertness and transparency. Natural mica is the most perfect of insulating materials and certain grades of mica possess the flattest surface of any material known to science. Despite these advantages, even a sedate reference work like the McGraw-Hill *Encyclopedia of Chemical Technology* dubs the mineral as a disease. The problematic nature of mica lies not in the versatility of the mineral but in its extraction and fabrication. Mica mining has always been characterized by its primitive simplicity. Even in the USA where a high degree of organization is the rule in most industries, mica mining was performed on a small scale by subsistence farmers in search of a supplementary source of income. The equipment used was fairly simple, mainly a winch for the bucket and a compression pump. Because of the very erratic occurrence of deposits, conventional drilling methods are not applicable. The irrationalities involved in estimating and locating mica reserves are compounded by the labour intensive nature of the mining operation in a country where labour costs are prohibitive.

This made it difficult for mica owners to compete with Indian mines. While the cost of production in the USA was about six dollars a pound, the entire extraction and processing of mica in India cost fifty to eighty cents a pound. Thus an international division of labour was set up between India and the USA. While extraction was carried out in the former, by labourers accustomed to earning less in a day than an American earned in an hour, the manufacture and consumption of the product occurred in the West. (Roy, 1952, p. 508.)

The export oriented nature of the technology deserves to be emphasized. The most extensive use of mica in India up to World War II was for ornamental purposes. The native physician used mica in the preparation of certain medicines. The consumer profile of mica in the USA stands out in sharp contrast. An American magazine article captures it in a typical bit of journalese.

At your breakfast table your toast is browned between red hot wires wrapped around plates of mica. If you decide on a little do-it-yourself painting, mica is quite likely to be in the paint you use. Your wallpaper, the tyres of your family car, your radio, your television and scores of modern conveniences all depend on their quota of mica. Even the artificial snowstorms that rage at the command of Hollywood studios

depend on this adaptable mineral, the snow is nothing but flakes of mica. If the American economy is suddenly cut off from its supplies of mica, there would be a sudden and almost unwelcome change in the daily habits of Mr and Mrs America, not to mention Susie and Junior.' (CGCRI, n.d., n.p., photocopy.)

The basic uses of mica can be divided into three categories: defence electronics, consumer electricals, and other non-electrical, uses. The largest use of block mica is as supports in electronic tubes and as backing plates in condensers. The largest non-electronic use is in household appliances like toasters and irons, and in incandescent lamps and fuse plugs. The electrical uses require splittings, which is mica of a slightly lower grade. Scrap mica, which constitutes 94 per cent of the mine output, is used mainly in the paint, wallpaper and rubber industries. (Roy, 1974, p. 56.) In the following section we shall describe the process of substitution as it occurred in each of these three sectors.

The obsolescence of mica in electronics began in 1940, when the biggest user of Indian mica, the US army, realized that its electronic and aircraft programmes would require unprecedented amounts of high quality block mica. America had to import its supply from India, which it considered an unpredictable source in the event of a war or an emergency. The US government first attempted to increase the productivity of its mines through scientized technology. This, however, was not fully successful. The onus now shifted to the research laboratories which were asked to provide alternatives and substitutes for mica. The US laboratories responded to the government's call to evolve a new system of classification that could result in a more economic use of mica than had been possible under the Indian system. As a result of their investigations, there was a permanent revision of specifications in favour of the lower grades of mica, specially in the radio industry and the aeroplane sparkplug industry, which used the best grades of mica. Simultaneously, a whole group of laboratories attempted to find alternatives for mica in various products. The laboratories of the General Electric Company, Corning and Dupont developed alternatives for the mica Capacitor. The MIT insulation laboratory under von Hippel went even further by using ceramic capacitors which could easily outshine the mica condenser. In fact, the first casualties of the newly growing materials science were the mica sparkplug and the mica capacitor.

The assault on the domain of mica did not lose momentum at the end of World War II. On 8, May 1950, the US Navy and the National Industrial Security Association convened a military-industrial round table. A convention of over seventy delegates, the invitees included delegates from all the top defence agencies, like the Batelle Institute and corporations with outstanding industrial research laboratories such as Dupont, General Electric and Bell Telephones. The proceedings of the meeting reveal a clear-cut policy concerning mica, which Admiral Rico Botta of the Navy described as a 'headache'. (Report Industrial Military Round Table, (IMRT), 1950, p. 5.) The decisions, based on government reports completed with the aid of the National Academy of Sciences, claimed that 'the mica industry all the way from prospecting to final fabrication does not fit the American pattern of mass production or the American standards of living, which called for efficient employment of well-paid workers.' (Report, MMAB, 1950, p. 52.) The report suggested that it would be very much in the national interest if synthetic mica or other uniform materials could be substituted for mica. The responsibility for finding alternatives and substitutes for mica was to be the role of the industrial research laboratories. Beginning after World War II, a quiet battle was fought between the industrial research laboratories of the military-industrial establishment in the USA and the scientists of the CSIR in India.

The scientists involved, first catalogued the strategies employed by their counterparts abroad and then attempted to counteract them. One of the most significant innovations introduced by Bell Telephones was a new system of classification for mica. Indian mica had been graded on the basis of a visual system based on colour. The Bell Telephones group devised a synthetic method of classification depending on the dielectric and physical properties of mica, utilizing the Q meter. Bell Telephones then summoned four capacitor manufacturers, Westinghouse, Sprague, Sangamo and Cornell-Dubilier, to make capacitors and run tests on them. The American Society of Testing Materials (ASTM) immediately accepted the Q meter as the mode of standardizing the evaluation of mica, rather than relying on subjective visual tests.

The Indian delegation to the 1950 International Standards Organizations led by K. N. Mathur of the NPL managed to ensure that the secretariat for two primary products, mica and lac, would be

located in India. This placed the responsibility for formulating standards for these commodities on India. This was an extremely important assignment, as one of the basic complaints of importers abroad was the difference in quality of the various batches supplied, usually a result of the manner in which mica was classified and graded. While clear and slightly stained mica fetched a high price, those with appreciable spots and stains were bought at much lower prices. 'Visual grading however was an extremely subjective and empirical phenomenon, like tea tasting'. (Interview, Ramamurthy, 1977.)

In 1950 Indian scientists in the NPL and the CGCRI associated with various ISI committees began agitating for the replacement of the visual by the electrical grading system. They pointed out the various advantages. The electrical system was less ambiguous. Further, unlike the existing system, which rejected spotted and stained mica a second grade and unfit for electronic use, the American system allowed the mica block to be of any basic colour, white ruby or light green, as long as it conformed to certain electrical characteristics. The scientists argued, 'as the electrical system of classification qualified mica previously considered visually unsuitable for capacitors, the mica supply for such use is greatly increased as compared with the older system'. (Ramamurthy, 1976, p. 771.) They also pointed out that standardization on an electrical basis would enable Indian owners to obtain better prices for their mica, and emphasized that it would rationalize market prices. For example, clear and only slightly stained blocks from Bihar and Rajasthan fetched on an average Rs 557,545 per tonne in 1975, while stained blocks from the same source fetched Rs 68,207. If electrical tests had been applied, as suggested by the ASTM, the stained blocks may have come up to the same standards as clear and slightly stained blocks and fetched the same price. (Ramamurthy, 1976, p. 771.) Detailed investigations by the CGCRI confirmed the NPL's argument. The scientists in fact showed with market statistics the remarkable fluctuations in mica from the same sources. In the absence of the electrical grading system, there appeared to be no standard formula for pricing between countries as the following table indicates. (Ramamurthy, 1976, p. 772.) The scientists then indicated that exigencies of supply and demand could not account for such large variations in price.

TABLE 7-1

Value per tonne of clear and slightly stained blocks from Bihar and Rajasthan (in Rs)

Country	1972-3	1973-4	1974-5
USSR	-	1,90,105	10,80,650
GDR	-	1,94,000	1,39,000
Italy	-	-	61,500
Poland	-	-	2,99,000
USA	-	6,93,000	-
Average	2,19,667	2,29,772	5,57,545

TABLE 7-2

Value per tonne of stained blocks from Bihar and Rajasthan (in Rs)

Country	1972-3	1973-4	1974-5
USSR	68,522	70,291	98,714
UK	20,775	10,833	34,714
Poland	53,429	51,600	31,308
Japan	29,678	30,755	45,125
Czechoslovakia	29,948	28,500	35,154
Bulgaria	-	-	53,654
Average	43,771	44,239	68,207

Insisting that, despite the existence of the Q meter for the previous two decades, the mica sellers still adhered to the visual classification, they urged the bringing in of sanctions to enforce scientific standards in India. They pointed out that in both Russia and America, which followed the electrical system, there existed an institutional system whereby standards formulated by scientists were followed. In Russia, standards had a legal status in much the same manner as any other law in the country. In America, standards were voluntary but implemented systematically by the industry. India had yet to devise a system whereby standards devised by scientists to improve efficiency, acquired legal sanctity.

By 1952 industrial research laboratories in France and America had devised a methodology whereby mica processing could be mechanized, instead of going through the tedious process of trimming, splitting, moulding and cutting. The credit for processing mica into continuous sheets belongs to Jacques Bardette. The Bardette process was worked out in France during the German occupation. After the occupation, plans were rushed through to

put the laboratory phenomenon of continuous mica sheets into pilot plant production. Scientists at the 1952 conference of the American Association of Electrical Engineers predicted that eventually this form of mica would replace mica splittings in all grades of micaceous insulation, and also find new uses in electrical insulation products, where mica splitting could not be used successfully. The political overtones of the Bardette process were explicitly stated at the conference:

The strategic value of these novel mica products in the present confused international picture is important. Mica is listed as a strategic mineral in rather short supply. With a large part of our muscovite mica coming from India, the inclusion of India in the Russian sphere of influence will pose a serious problem of supply. Mica paper can be made from domestic mica of many sources. If the cold war should suddenly get hot, enemy action could make the transportation of mica from India hazardous and imported mica would not be attainable in adequate supply. This new form of mica could certainly make up for the loss of Indian mica in most of our micaceous insulation. (Report, dielectrics sub-committee, 1952, p. 465.)

Ironically owing to its outstanding properties, even heavy electrical complexes in India have started using imported mica paper in place of the mica splittings in which India holds a monopoly, and which is in fact the mainstay of the Indian industry.

The last major phase of the co-ordinated assault on mica was to synthesize mica. When World War II ended, the US army despatched two famous intelligence teams to investigate the latest developments in scientific research in Germany. One group, the famous Alsos mission, investigated German research on the nuclear bomb. Another was sent to investigate whether Germans had synthesized mica. They found that the Germans under Wilhelm Eitel had achieved some success and a decision was made to transfer the team to America. In 1955 the first large-scale pilot plant for synthetic mica came into operation. Synthetic mica, however, has still not gained commercial importance.

The scientists of the NPL and CGCRI attempted to find increasingly diversified uses for mica. They tackled two fronts simultaneously: the export market and the internal market for mica. The NPL in 1952 attempted to fabricate silver mica capacitors (see Chapter V). However, they later found that by the sixties silver mica capacitors had lost the market to plastic films. They also discovered that the use of high quality mica in electronic

applications was slowly decreasing abroad as a result of substitutes. Mica was no longer considered indispensable for many applications. 'While no single material, natural or synthetic has got all the qualities of mica, a host of alternative materials have been developed which have some, though not all, of the outstanding characteristics of mica. Materials like polystyrene, stynoflik, heat resistant glass, alsifilm, ceramics, etc. have been competing with mica and mica products in quite a few fields of application.' (Roy, 1974, p. 60.) The scientists emphasized the need to monitor such information. 'No information is available regarding specific fields of application, the exact end use pattern and the factors responsible for preferring the substitutes. Comparative merits and demerits of mica products vis-à-vis the substitutes developed are also known only in a general way. It is not known precisely what has been the impact of the substitutes on the present and future consumption patterns of mica products in a particular field of application in various consumer countries.' (Roy, 1974, p. 61.)

The scientists emphasized that the only way to save mica was to create more demand in India itself. The problem lay in the sociological profile of the mineral, which catered basically to defense electronics and upper and middle class consumers. They pointed out the necessity for a long-range, continuous, in-depth technical market and research programme. 'The superior qualities of mica compared to other materials if any, have to be established and highlighted with a view to replacing the substitutes for mica with mica. Besides, new uses and new fields of applications for mica will have to be invented. Research so far done in foreign countries was carried out solely for developing substitutes for mica. Special efforts will have to be made to develop new uses for mica, particularly for low quality mica which constitutes the main bulk of production.' (Roy, 1974, p. 61.)

In a report to the Institute of Foreign Trade Ramamurthy pointed out that the cost of production of crude mica and scrap was Rs 807 per tonne in 1966 and that its export value was Rs 500 per tonne from 1967 to 1974. It was thus clear that the export of scrap and waste mica was being subsidized to the extent of over Rs 300 per tonne, which meant a total subsidy of Rs 3.2 million in 1970. In 1975 the subsidy had risen to Rs 24.3 million. The scientists suggested that part of this subsidy could be used for setting up a well organized manufacturing unit so as to make

quality products of mica paper, micanite, which would be internationally acceptable. (Ramamurthy, 1976, p. 769.) It is in this context that scientists referred to the NCST plan for a mica laboratory to create alternative, and possibly internal markets, for this mineral, so closely beset by consumer wars. But the necessity of a change within the problems of science in India was also emphasized.

The scientists further made an important point regarding the choice of problems and the manner in which it affected markets for commodities. This had to do with the choice of problems of science in India. They emphasized that from the perspective of industrial research the greatest danger to primary products came from the value systems of Indian science, where scientists working on primary products were hardly accorded recognition. In this context, they contrasted the vast amount of research done abroad with the almost complete neglect of mica and primary products in industrial laboratories in India. It is this, they believed, that was contributing to the virtual extinction of mica as a major industry. A similar argument stated explicitly by Hans Singer in an article in which he refers to the tendency of scientists and technologists in poorer countries to behave as members of a scientific community with its centre of gravity in rich countries rather than as citizens of their own countries. 'If you want a Nobel prize or recognition from your peers, or even your articles published in leading journals, you must work on the frontiers of science. But it is the rich countries that determine what the frontiers of science are.' (Singer, 1975, p. 193.) In this connection Ramamurthy referred to the changing paradigms in materials science institutions abroad. He pointed out that materials science as a subject was virtually created when it was realized that materials problems constituted serious impediments in atomic energy and technologies related to defence. The US government realized that these problems could not be solved without progress in the scientific understanding of materials. US federal agencies such as NASA, the AEC, and DOD resolved to share the responsibility of investing 8 million dollars in this new field. Ramamurthy emphasized that such a reorientation of federal funds had an impact on the choice of problems in the area. He pointed out that recent energy problems of advanced industrial societies had led to another shift in focus. The scientists underlined that neither the Indian government nor the professional academies

had made a corresponding move in the face of a threat to primary product. Singer's comment thus becomes valid for he pointed out that

We can consider research and development as an established industry where outputs depend more or less predictably on the inputs. If you feed certain problems at one end, the solutions of these problems will pass out at the other end. If you feed into R & D machinery the problem of synthetic coffee, synthetic cocoa, or synthetic tea which is indistinguishable from the natural product or even superior to it, we need not doubt that such substitutes will pass out in due course. But we need hardly underline what this will do to the economies of countries such as Kenya, which relies on coffee, or Ghana, which relies on cocoa, or Ceylon, which relies on tea. The point is that decisions of what problems are to be fed into the R & D machinery are made in the rich countries in the light of their own priorities and requirements'. (Singer, 1975, p. 193.)

In this context the NPL scientists bitterly commented that, while the NCST had approved of an industrial research laboratory for mica, nothing tangible had resulted from the suggestions. They warned that 'it was high time that something was done in earnest, otherwise mica may go the way of the indigo industry.' (Roy, 1974, p. 61.)

III

In the previous section we concentrated on the negative aspects of the diffusion process, namely obsolescence. We tried to emphasize the role of the laboratory in an industrially developing society in anticipating and preventing the destruction of a market for primary products. In this section we shall turn to the more positive aspects of the diffusion process and examine the possible role of research laboratory in creating a market for a mass-produced ruggedized radio. We shall attempt to show how the laboratory utilized certain advances in science to help create a bigger market for the radio.

The electronics components group of the NPL had been recruited from industry, where its leader, while technical director of National Ecko, had tried to produce the first indigenized receiver, the Hindusthan Radio. This radio was not a commercial success, however, and Ramamurthy realized that a more feasible strategy was to concentrate on community receivers. The NPL was

associated with the standardization of radio receivers from 1952.

The history of the community receiver goes back to 1939 when the Madras government suggested a scheme for the free installation and maintenance of community receivers. The idea was well received and by 1947 over 841 sets were in operation. The community receivers used in Madras were standard domestic receivers which operated on a 6 volt car battery and which demanded constant recharging. The set needed two batteries, one on charge in a service station and the other powering the radio. Every fifteen or twenty days the charged accumulator had to be brought to the village and the discharged one taken back. This added to the expense of the community receiver system, which cost about Rs 400 per annum. Despite the expense, community receivers proved fairly popular and by 1952, Madras state possessed 1,800 sets, with 67 accumulator charging stations to maintain these sets.

The interest in providing reception facilities soon became widespread and in many states domestic receivers were installed for this service. The radio industry evinced a keen interest in producing specialized receivers to satisfy this demand. However, it was handicapped by the lack of standard specifications for which it could design a suitable receiver. In 1954, in order to encourage rural listening and to accelerate the pace of installation of community receivers in villages, the Ministry of Information and Broadcasting, offered to bear half the cost of the receivers. The ministry undertook to co-ordinate all the requirements and placed bulk orders. The procedure for the placing of orders was that purchases would be made by the Directorate-General of Supplies on a tender basis. A standard performance specification acceptable to industry, the user, and the purchasing authority thus became necessary at this stage. The Radio Equipment Sectional Committee of the ISI, which included the NPL scientists, was called on to provide specifications. (Interview, Ramamurthy, 1976.)

Before a suitable design for a community receiver could be worked out, the electronics components group remarked that the radio itself had to be visualized as a part of a socio-ecological system. Ramamurthy emphasized 'the necessity of a study of the conditions obtaining in villages before a community receiver could be designed and marketed. It had to be tested out for economic feasibility and environmental durability'. (Ramamurthy, interview, 1976.) The work of the NPL group in this context first

led them to conceptualize the problems of designing and marketing a low-cost radio.

They began with the obvious fact that the radio had basically to cater to a nation of villages, as 300 million out of the then total population of 350 million lived in rural areas. There were hardly any roads leading to these villages, which were approached by dirt tracks that were impossible during the monsoon which lasted from three to six months. Only 1.5 per cent of the villages were electrified and prospects for electrification were not high because of the high financial outlays needed. There were hardly any technicians in the villages except perhaps blacksmiths or carpenters. The overriding concern, however, was the low per capita income of the villagers. (Ramamurthy, 1973, Annex. I, p. 2.)

With the socio-ecological concept of the village in mind, the electronic components group then examined the possibilities of a villager owning a radio receiver. Before World War II, a mass-produced broadcast receiver was priced at 7.50 to 10 dollars. Post-War prices were about three times higher and the design conditions for the operation of a receiver under village conditions precluded the possibility of mass-producing receivers at less than 30 dollars each, i.e., Rs 150. As this was nearly 50 per cent of the average annual income of the villager, the scientists decided that in the existing stage of development, it was desirable to have a community receiver. (Ramamurthy, 1973, Annex. I, p. 3.)

The receivers had to be battery operated as only 1.56 per cent of India's villages were electrified; but dry batteries were an expensive source of power. There were also hardly any repair or maintenance facilities in the villages and receivers needing repair had to be brought to the cities. The lack of minimum facilities naturally increased the cost of maintaining receivers and in effect they could be out of working order for considerable periods. The NPL found that such was the situation with community receivers bought as common property by villagers and installed for their benefit. All these considerations pointed to the conclusion that, if broadcasting facilities were provided at the village level, a proper maintenance organization was essential to assist the village periodically. It demanded that state governments maintain co-ordinating offices and a string of repair depots at strategically situated towns and villages from which the surrounding areas could be served.

Maintenance problems and the difficulties of transport to the village communities were so great that the NPL scientists attempted to revise the construction of a receiver. In this design the receiver was divided into three units or cells, where the sections of the radio were hermetically sealed off from one another. They were also provided with multiple sockets at the rear which enabled them to be plugged into the cabinet at the appropriate place. The scientists suggested that one set of spares be provided for each group of villages. In case a unit became defective, the village headman or the school teacher plugged in the good unit he had as a spare. The defective unit was then sent by runner or post to the servicing station and had to be designed to stand rough handling. The cost of such a receiver was fairly high as it needed to be as hardy as military equipment. In addition, the receiver had to be battery operated and subject to restriction in tuning. The main reason for the latter was not the prevention of listeners tuning in to stations other than All-India Radio, but mainly conservation of the battery. The dry cells which were used for powering the valve-type community receiver was comparatively expensive (Rs 95 exclusive of taxes), and too frequent a displacement of batteries was not economically or organizationally feasible for the Rural Broadcasting Corporation. The scientists thus abandoned the idea of a community receiver as inappropriate at the then existing level of technology.

The scientists sought further possibilities in a technological breakthrough and found it in that archetypal product of the industrial research laboratory, the transistor. Small, portable transistors, instead of two heavy valve-type receivers, could be easily built with sufficient reliability and would overcome the need for an intensive servicing or repair organization. In 1952 the NPL group suggested that the possibilities of a low-cost ruggedized radio lay in the transistor. They also realized that battery power was too expensive and sought an alternative source in thermoelectric generators. The combination of the two, they suggested, would make radios cheaper and more durable. The transistor had great advantages over the valve because of its increased reliability, practically infinite life, and economy in power requirements for its operation. Because of its simple mechanical features the scientists felt that the transistor was potentially a low-cost device, and predicted that possible improvements in transistors were likely

with technological advancement and a better understanding of solid state theory. The scientists also sought to replace the battery pack with a thermo-electric generator, pointing out that the USSR had developed one which used 100 cc. of kerosene per hour to deliver 90 volts at 20 MA; and they emphasized that, with the advent of transistors, power requirements would be drastically curtailed, which would make the generator yet more economical. Further, kerosene was available even in the remotest hamlet. It was cheap and they suggested that a generator could easily be designed to fit a Dietz-type hurricane lantern which could easily be used in the villages. Finally, since there were no moving parts, the thermo-electric generator was a robust device and unlikely to be damaged easily in transport or service.

Research with transistors was still proceeding at Bell Telephones when the NPL began advocating the use of transistors to replace valves in community receivers. In 1952 the transistor was still a temperature-sensitive device. The NPL reports demonstrated that the sensitivity of the transistor to temperature could be overcome by suitable circuit techniques, or by the utilization of other components, such as thermistors. These would, however, increase the cost and complexity of the equipment and the NPL sought to counter-act this by devising a community receiver of hybrid design. The studies demonstrated that, compared to a valve receiver, the hybrid achieved a power economy of 50 per cent and a fully transistorized community receiver achieved a battery power economy of 66 per cent. The fully transistorized receiver was, however, disproportionately expensive and the NPL reports argued that, in the current state of technology, the initial costs of the receiver outweighed the additional available economy in battery power. The scientists emphasized that the transistor was a potential low-cost device and that it was only a question of time before a better understanding of solid state technology would render feasible a fully transistorized community receiver.

The NPL's work in the design and development of community receivers between 1950 and 1959 was to provide it with a clear conception of the radio as part of a wider socio-technoecological system. This knowledge was to prove extremely useful when UNESCO suggested a plan to cater for the untapped market in radios in Asia and Latin America. UNESCO, which was concerned with mass communication in developing countries, realized

how essential a radio was in propagating literacy, public health and family planning programmes. It appointed a team of experts to visit these countries to report on the existing coverage and the distribution of listening facilities. The UNESCO report, which became available in 1965. The committee observed in its section on India that 'there is no reason why a medium wave set should not become popular with the masses provided of course that the price of the set is much below. . . Rs 125' (UNESCO, 1965, p. 15). The report estimating that there was an untapped demand for 400 million radios in South, South-East Asia and Africa. The radio industry in India was naturally excited by this prospect and through the Directorate-General of Technical Development (DGTD), the government held discussions with representatives of industry on the feasibility of manufacturing a low-priced transistorized receiver.

The meeting was held in Bombay on 26 June 1964. It noted that, while the government had already accepted the need for the indigenous manufacture of low priced sets, the production facilities for low-cost transistorized sets were virtually non-existent. The meeting appointed two committees to investigate the technical and commercial aspects of the problem. The former was to draw up specifications for a single-band medium wave transistorized radio and the latter was to work out the cost of production on the basis of the report of the technical committee.

Based on UNESCO's specifications, the commercial committee worked out the cost of the receiver and concluded that the ex-factory price of the set, if manufactured in the organized sector, would be Rs 102, and Rs 90 in the small-scale sector. However, the set would be made available to the consumer by manufacturers of both sectors for Rs 140. The committee observed that, while the small-scale sector had the advantage of lower production costs, its sales promotion and distribution would be more expensive, thanks to a lower volume of sales and competition from established brands.

The scientists of the Electronics Components Group of the NPL, who received the report, felt that at the costs posited, the possibility of a low-cost receiver was remote. On the basis of their experiences on the community receiver project they formulated a critique of the DGTD report. In an article in the *Eastern Economist* in 1967 Ramamurthy pointed out that the committee

failed to conceptualize the radio within the socio-economic environment of a developing society. He commented that the radio in an affluent society was regarded as a toy. The pocket radios produced in Taiwan for the American market were generally discarded when damaged. They cost a mere 2 to 5 dollars and had obsolescence built into them. Manufacturers in India seemed to consider a set priced at Rs 160 a low-cost set. Such a conception restricted the diffusion of the radio to the more affluent classes. The radio, he pointed out, was not a luxury item for entertainment but a crucial agent for literacy and development. To bring down the price of the so called low-cost receiver, it was essential to plan on a really large scale, much larger than what the largest manufacturers in India were operating on. The biggest production unit, he pointed out, was producing a mere three hundred receivers a day. Another way of cutting down the cost of the radio, was to innovate by looking for new methods in marketing and distribution which were quite different from those followed at the time. Marketing and selling costs were of the order of 37 to 56 per cent of the cost of the radio and using NCAER data, Ramamurthy tried to visualize a different way of distributing radios in the urban market.

Ramamurthy found that in the corporate sector there were 26,000 joint stock companies. There were 8,700 registered factories employing a total of 2.9 million people. The railways employed 1.2 million, communications 0.4 million and, 'if we add government employees in various departments in the centre and the states, we arrive at a total figure of around 10 million. The average salary of workers in this sector is about Rs 15,000 per annum. If we take government officers in the higher income brackets, we can estimate about one million in all who can be expected to buy sets which are in the higher price range. This leaves us with 9 million workers with an average salary of about Rs 15,000 per annum. These are likely to be the potential customers for low-cost receivers.' (Ramamurthy, 1967, p. 1.) Ramamurthy suggested that the low-cost receiver could be distributed through these organizations to their employees at a nominal price. Some of the organizations could even offer hire-purchase terms to their employees. He stated that there may be doubts about the feasibility of this scheme as the radio receiver was a complicated piece of equipment requiring servicing facilities. However, Rama-

murthy pointed out that the problem of servicing was not a major one any longer, given the advances in solid state technology. 'A transistor receiver is much more rugged than a valve. These receivers, if produced to specifications, would give trouble free service for a long period. In order to reassure customers, the factory might even offer to take back any receiver that became defective within a period of one year and replace it with a new one.' (Interview, 1976.) Ramamurthy then cited the example of co-operatives which brought down the cost of the receiver. The Envoy radio was sold through the Delhi Super Bazar and other co-operative stores throughout the country. Over 7,000 sets were being manufactured every month and sold at a price of Rs 85.

Ramamurthy went on to make a careful analysis of the component cost of production and estimated that the factory price could be brought down to Rs 65. If the above premises were accepted, there was the necessity for an organization to produce these receivers. It was doubtful whether any single factory in the private sector could undertake such a large production. The NPL suggested the establishment of public sector undertaking with a production capacity of one million receivers.

The articles of the NPL scientists in various journals and newspapers reopened the possibility of a low-cost receiver. Discussions were initiated with established radio firms like Murphy, Telerad and Mulchandani. On 20 October 1967 Mulchandani Electrical and Radio Industries submitted a proposal for a low-cost one-band receiver for Rs 75. (Letter, No. 2, 1967.) The Mulchandanis, who manufactured the Bush radio, suggested that a successful remunerative programme demanded that the import content of the receiver be increased in order to achieve economy. The proposal, however, made it clear that this was merely a short-term suggestion and that the eventual solution was indigenous mass production at international prices. The company offered to produce 187,500 receivers for 1968-9. It also offered a phased programme for the manufacture of receivers reaching a target of 1,000,000 in 1977. The company applied for an increase in licensing capacity of an additional 60,000 receivers. The proposal concluded by claiming that the company was ready to start its one-band project provided the government allowed for '(a) an increased sanctioned capacity, (b) import license on the basis of increased capacity, (c) the availability of transistors at

Rs 10, (d) reduced price for the NPL rods and cores.' (Letter, No. 2, 1967.) The proposal emphasized that transistor costs constituted literally one-third of the material costs, and that a 50 per cent reduction in the price of transistors would make a significant contribution in bringing down the cost of components.

Telerad were also prepared to take up the production of 2,00,000 receivers. S. R. Jawarjajka of Telerad wrote to Ramamurthy on 10 May 1967, saying, 'I am prepared to take up the production of 2,00,000 such receivers within three months provided that you assist us in persuading the Defence Ministry to get us transistors at a concessional price only for making the cheap priced radios, and also your assistance in getting some of the components manufactured by your institute at the concessional price.' (Letter, No. 3, 1967.)

The Ramamurthy then had discussions with Dr Behram Wadia, Managing Director of Semi-conductors (India) and Baliga, Managing Director of Bharat Electronics. Both Wadia and Baliga agreed, in principle, to offer a set of six transistors and one diode required for a single-band transistor receiver conforming to ISI specifications at Rs 10. The price of one set of BEL transistors was Rs 23.27. Baliga however stipulated that adequate measures should be taken in order to ensure that the transistors, supplied for the low-cost receiver, did not find their way into the resale market. On 25 April 1967 Ramamurthy wrote to Mr Agarwal, Joint Secretary in the Defence Ministry, suggesting a *modus operandi* for the operation. He suggested that the Ministry should invite selected manufacturers to indicate whether they were prepared to make a low-cost receiver at the stipulated price of Rs 65. The manufacturers should further be assured that they would get transistors at a concessional price, amounting to 50 per cent of the market price. The low-cost receiver should meet the relevant ISI/UNESCO specifications. The letter ended with a request for immediate action. 'As you know, Mr Baliga will be laying down his office this June. Unless the matter is pursued immediately, the new incumbent may find it difficult to commit himself, without familiarizing himself with the activities of BEL, particularly in the components field.' (Letter, No. 1, 1967.)

On 19 June 1967 Ramamurthy informed Mulchandani about his discussions with Baliga at BEL and the Joint Secretary, defence. The letter advised Mulchandani that, 'in order to facilitate the

government to take any initiative in the matter of getting a special price for low-cost receivers, it is better if firms in the organized sector make an offer to the government saying that they are prepared to produce a low-cost receiver at a price, ex-factory, of Rs 75. Such an offer from firms would help the committee to proceed further and arrange for the reduction in price for transistors and possibly other components.' (Letter, No. 4, 1967.) By 3 July 1967 the Government of India had indicated that it would be placing a contract order for three lakh pieces for mass distribution in the country.

The entire negotiations were however upset when the then Finance Minister, Morarji Desai, imposed an excise on valves and transistors. Firms like Mulchandani and Murphy, who had agreed to market a low-cost receiver for Rs 75, now insisted that they would market it at Rs 95 and Rs 99 respectively. Ramamurthy made one last effort to save the project. He wrote to Mulchandani arguing against his contention that the radio could only be marketed at Rs 95.

My main contention is to pinpoint that we should aim at increasing the production of radio receivers many fold if we are really to have a viable component industry which can produce components at international prices. I entirely agree with you that we should at the earliest possible stage stop providing foreign exchange for component imports. For the component industry to grow and to have volume orders which will make it economical to produce them at international prices, the receivers have to be at a price which will be within the easy reach of a very large cross-section of the people. This fulfils two objectives: (a) availability of listening facilities to a much larger number of families than at present; (b) adequate profits to manufacturers by mass turnover with small profit per receiver.

The philosophy of the whole approach is not that a few thousands of sets can be sold at a higher price to people who can afford to spend Rs 95 or Rs 100, but it has much larger significance in the very implementation of the Bhabha Committee report. The electronics industry can grow to the dimensions which Dr Bhabha envisaged only if its foundation is soundly laid on a large viable component industry. The major consumer of these components will be the entertainment field, and in our country the only electronic entertainment equipment that can possibly be sold in quantities large enough, is the low cost receiver. We are still quite far from a mass market for TV receivers even if they are produced at economic prices.

If you accept this premise, it is axiomatic that your price for the low-cost

receiver will have to be such that the dealer and the distributor get their earnings by large turnover rather than comparatively large profits on every radio. . . . I suggest that you kindly go over your proposal for the manufacture of low prices receivers at Rs 75 as a selling price. (Letter No. 7, 1968.)

In his reply to Ramamurthy, Mulchandani observed: 'With the duties the Finance Minister has deemed fit to impose on valves and transistors, I really do not know how we, in the industry can think of a set for Rs 75. Our entire pricing of radio receivers will be affected by the new levy'. (Letter, No. 6, 1968.) The radio industry's chagrin was obvious from a supplement issued a year later. It remarked that the politicians 'heavily tax the radio as if it were a bottle of alcoholic drink the public must be saved from. Whether it is excise levy or sales tax, radio licence fee or octroi duty, the radio is taxed like a luxury item.' (*Times of India*, 1969, p. vi.)

The next major attempt to produce a low-cost radio began in 1967 when the CSF sent Ramamurthy a project report offering to give all the technical data, assembly drawings and quality control and test procedures for the mass production of receivers. The CSF was not interested in setting up an Indian subsidiary. It was ready to offer one million receivers for a lumpsum payment of 50,000 francs. It made an offer on 1 January 1968 for the manufacture of the 'Clarville Junior' set and dispatched two prototypes for tests to the NPL. The Clarville set was elegantly designed and had obviously been satisfactory for the French listening public. But it was not adapted to the conditions of a developing society. 'It was beautifully designed but as fragile as a doll.' (Interview, Ramamurthy, 1976.) The printed board could hardly stand the rigours of transport and cracked in both prototypes. The battery compartment too could not withstand rough handling. Ramamurthy suggested to BEL that they set up an ancillary unit to assemble a more practical and hardly version of the Clarville. In a letter to the Managing Director of BEL, he wrote:

By doing this you will not be cornering the entire market for radio receivers as the production is expected to be of the order of four to five million by 1970-1. But there is this factor of pace-setting and horizontal control envisaged by Dr Sarabhai which means producing sets of a standard quality according to CCIR/ISI specifications which can find a

ready market for exports particularly in East Africa and the Middle East countries, where such sets are selling for approximately 9 pounds. We have to remember that the set we have in mind is not to be compared with a 1.50 or 2 dollar set which are just toys and have very little entertainment value. The sets we have in mind can be used by the family for listening to a musical programme with adequate volume and with little distortion. The battery life will be about four to six months depending on the use, as the set will use a larger size of cells.

BEL showed an initial interest in the proposal but eventually abandoned it.

By 1972, the radio industry, was in the doldrums. The Electronics commission, established in 1970, presented a series of reports analysing the structure of the market. The Industrial Planning and Advisory Group (IPAG) of the Electronics Commission reported that 'the demand for radio receiver sets is tending towards a plateau in the urban market, consequently the sales turnover of those manufacturers who have been relying on these markets is on the decline and production is much below licensed and installed capacity'. The report stated that it was imperative for new markets to be found to sustain the radio industry, and referred to the necessity of tapping the rural market which had benefitted from the green revolution. It emphasized the necessity of a co-operative approach between various institutions to create a boom in the industry. There seemed to be no consistent follow-up in the Electronics Commission policy of ruralizing the radio. By 1975 it published a report advocating the establishment of FM radios to check the recession in the industry.

Ramamurthy argued that the Commission's study of the possibilities of the FM radio was uncritical. FM was once again merely catering to the already saturated urban market. 'To offer FM as a panacea for the recession was simplistic. The recession was caused by two major reasons—the almost complete lack of sales outlets in rural areas and the simple fact that there is no hope for the rural or urban poor to buy a radio at current prices.' He argued further that the introduction of FM would not bring about the indigenization of the radio industry. Because it has to deliver very high frequencies, an FM set requires a more complicated circuitry. Existing AM sets cannot be profitably modified to receive FM broadcasts. Also, unlike the AM receiver which is almost totally indigenous, manufactures of FM sets would have to

import certain components which in turn would make it more expensive. The IPAG report claimed that FM sets would be manufactured for Rs 200 to Rs 250, but it also observed that the consumer would be unlikely to buy an FM set alone as AM-FM models would be preferred. The report held that these radios would cost around Rs 300. Ramamurthy pointed out that Philips, who were the first to introduce the FM radio, priced their three transistorized models between Rs 700 and Rs 1,225, exclusive of taxes. The introduction of the FM radio would also tend to throw several small radio firms out of business and large firms with foreign patents had already started making FM radios for the market. Philips were manufacturing about 5,000 FM sets by 1974. (Interview, Ramamurthy, 1978.) Ramamurthy emphasized that the multinationals, which had the necessary infrastructure to manufacture FM radios, would dominate the market.

Reflecting on his experiences, Ramamurthy observed that there was a general tendency among scientists to consider the radio as a primitive commodity, given the rapid advances in solid state electronics. He added, scientific progress need not always imply obsolescence. A radio abroad might be regarded as a toy with built-in obsolescence, but there was no need for scientists in India to accept such a definition. They could use the latest advances in solid state physics to produce a cheaper *ruggedized* radio, robust enough to withstand rough handling and heat, humidity, insects and the other travails of a tropical ecology. In that very act, *ruggedization*, which was a military concept, acquired a new social meaning. Such a radio, with built-in mechanical and electrical stability, could be sold through unorthodox outlets such as post offices, co-operatives, village shops selling matches and soap. However, this blending of the scientific and the social establishment has eluded the former.

Ramamurthy added that the attempt to create a market of this nature for the radio would also serve to bridge the dualisms between research in entertainment electronics, and that on the more sophisticated professional grade equipment.

There are two aspects to the latter; one is the sophistication in circuitry and the other is the reliability aspect. When we talk of a 'ruggedized' rural receiver all the tricks of the trade for insuring reliability in professional equipment are needed for these two. In addition, the latest in components

technology, such as integrated circuits can be used to increase reliability and to bring about further cost reduction. Thus, a very large demand for these more sophisticated components will be created. So, doing R & D in this field will dovetail nicely with the R & D effort proposed to be put into the field of professional electronics and be its beneficiary. (Ramamurthy, 1974, p. 3.)

CHAPTER 8

CONCLUSION

This study has attempted to provide a sociological understanding of industrial research in a developing society. It began by seeking to locate the problem historically and argued that the debates on industrial research were about the very directions Indian society was to take. The decision to establish a chain of industrial research laboratories was a part of a bigger choice, a conscious commitment to heavy industrialization. The scientists of the *Science and Culture* group, who helped crystallize this decision, realized that the industrial revolution in the west was not based on any systematic use of science as we know it. They argued, however, that industrialization in the twentieth century faced two imperatives: first, the necessity of planning and, secondly the need for a scienticized technology. As late comers Indian scientists understood that planned industrialization had to be based on scienticized technology and in this context the National Planning Committee under Nehru, which included scientists and engineers like Saha, Ghosh and Visvesvaraya, gave a prominent place to science in independent India. The establishment of the industrial research laboratories was not possible within the colonial framework. With the advent of Independence, Nehru and Bhatnagar laid the foundation for the entire network of laboratories that we know as the CSIR.

Implicit in the views of the leaders was a belief that investment in science, especially in fundamental research, would lead to technological prosperity. This conception was based upon the econometric conclusion that a positive and direct relationship existed between investment in science and economic growth. What it failed to realize, in Ben David's words, was that 'the existence or absence of a systematic positive relationship between scientific and technological growth is not something given and inherent in the nature of the case, but a state determined by

entrepreneurial activity.' (Ben David, 1968, p. 56.) The protagonists of industrial research failed to recognize the disjunctions between science and technology.

This study has also sought to understand these disjunctions. Beginning with an attempt to pin point historically the process of industrial research within the wider process of the institutionalization of science in India. Industrial research represented the third phase of the introduction of western science in India. The first phase was the era of the great surveys, which involved the establishment of a host of field organizations under the inspired initiative of the Asiatic Society. The work done by the society's early members in the fields of botany, geology and zoology was basically an extension of 'the overall European scientific effort, about which there was hardly anything 'Indian' except the objects of research, the living as well as the non-living belonging inseparably to the geographical world of India.' (Sen, 1970, p. 3.)

The second phase saw the growth of the professionalization of science and its consequent Indianization. The development of science in India began as part of the wider nationalist effort and revival: in this phase the first great institute of research under Indian control, the Cultivation of Science Laboratory, was established. But the founders made no attempt to link science and technology. In fact, they asserted the primacy of science. The debate between Sircar and his opponents was over the possibility of combining the two. Amritlal Sircar's exasperated wish that the phrase 'applied science' should not have been invented sums up the disjunction between science and technology in that era. The establishment of University College of Science at Calcutta did little to integrate science with the economy.

It was only in the third phase, as the nationalist movement gained momentum, that an attempt was made to link science and technology. The Indian Industrial Commission of 1916 visualized science and technology as parallel processes. To the grass-roots engineers who gave evidence before it, technology bred on technology, without necessarily requiring the formal impetus of science. Scienticized technology was merely one part of the industrial process. The scientists of the *Science and Culture* network posited a more encompassing relationship, where science gave an impetus to technology. The manner in which the *Science*

and Culture group posited the argument has been examined in some detail and we have emphasized that the scientific leadership in India failed to think of institutional solutions to transcend the dichotomy between science and technology. This is obvious in the speeches of Saha, Ghosh and Ramnath Chopra. Chopra's observation at the National Institute of Sciences is relevant here: 'it's a truism . . . that the discoveries made in the domain of pure science may and often find application in industries at a later date, and its industrial application, though its precise form cannot be foreseen at the time, has come to be an accepted incident in the after life of a discovery.' (Ramnath Chopra, 1940, p. 29.)

The writings of the *Science and Culture* group postulated not only a discontinuity between pure science and applied science but between research and development. J. C. Ghosh's contention that scientists should not be bothered with the latter is relevant here. The task, he said, should be left to the National Research and Development Corporation. The disjunction between science and technology is implicit in the Hill Report, which suggested that scientific research organizations should no longer be under specific user departments. Hill suggested—and Saha concurred—that all scientific departments should be centralized under one structure, but that development, i.e. the application of science to practical problems, should be the responsibility of the individual user departments. The scientists of the *Science and Culture* group, while advocates of industrial research, were inhabitants of universities, which sociologists have proved to be the domain of pure science. Their contempt for industrialists asking for applied science is obvious in their numerous editorials. In fact, they saw applied science as an imposition, a threat to the intellectual integrity of science and echoed Thompson's statement that pure science brings revolutions and applied science reforms. But they failed to work out how science was to be translated into technology. The disjunctions they posited between pure science and applied science, between research and development, and development and production were resolved only two decades later.

The study of the NPL, which was supposed to spearhead the technological revolution, helps us understand how the scientists, many of whom were recruited from universities, learnt to bridge the dichotomy between science and technology. During the

euphoria of Independence, they helped foster the myth that investment in science would lead to technological prosperity, and questions as to what science had offered were few and far between. One reason for this was the protection Nehru gave to the scientists. The questions, however, were repeatedly raised in the post-Nehru era.

In Chapter IV we catalogued the various attempts to work out a definition of the industrial research laboratory, and tried to understand this exercise as an act of classification, an attempt to relate a set of categories so that they fitted the new system. The questions they raised were basically this: if the university was the domain of pure science, and technology the realm of industry, what then was the industrial research laboratory? As early as 1950 the scientists intuitively perceived it as a kind of half-way house, but failed to go beyond this. The dominant world of the NPL was the world of pure science. As a social community, it was a well articulated one, a world which saw the learned paper as a gift. It was a hierarchical universe, where each scientist knew his place. The world of the factory was also a definite one. It was the domain of technology, of production, gauged in terms of efficiency and profit. The world of industrial research was in limbo. It possessed elements of both the university and the factory, and yet was neither. Chapter IV attempted to trace how the scientist worked out a definition of the laboratory.

The initial attempts of Blackett were aimed at managerial solutions, which were administratively quick but sociologically inadequate. Blackett dichotomized the laboratory. He suggested that the pure science divisions be transferred back to the university and the developmental units transformed into fully-fledged factories. Blackett believed that a whole section of the NPL, comprising the divisions of solid state physics and low temperatures, was for all practical purposes a university department playing truant. He wanted it to return to the domain of pure science, the university. Blackett felt that the growth of fundamental research required an academic atmosphere, which implied lectures, colloquia, seminars and most important, students. Simultaneously, he held that the development-cum-production units, like the Electronics Components group and the Glass Technology unit, should be transformed into independent manufacturing organizations, to be managed like a firm.

The Committee that followed Blackett realized that such an argument would not do. It attempted to struggle once again with the categories of science. Following Blackett, it admitted that 'existing within the NPL within one organizational set-up were many types of activity which for their growth required different organizational structures' (Menon Committee Report, 1963, p. 8). Vaguely implicit in the Committee's report was the recognition that the industrial research laboratory was a hybrid. Any attempt to understand it demanded an understanding of how much of the scientific technological spectrum it encompassed. The primitive distinction between pure science and applied science was inadequate. The classificatory systems had to devise new categories to account for the diversity of activities. It was Kitchlu who first emphasized the importance of objective basic research. The category posits a liminal creature, fundamental or basic research which is no longer academic but which has been re-oriented to serve the long-term interest of industry.

Kitchlu defined the NPL as a mission-oriented laboratory. He argued that the bifurcation of the laboratory into two parts, one oriented to the university and the other to industry, was not correct. The two wings were complementary and should sustain each other. In Blackett's proposal, a discontinuity was posited between the two units and the work of the two units could not be correlated as the centre for advanced physics was supposed to do academic research unrelated to industrial needs. Kitchlu intuitively realized that any division of labour presupposed a hierarchy, and a hierarchy between basic and applied research would impair the functioning of an industrial research laboratory. The scientists realized that the problem of the industrial research laboratory required a wider anthropological understanding as the problem was two-fold: conceptually the categories of science and technology demand a particular relationship between pure science, applied science and technology; and institutionally an organizational system had to be created and maintained. This had to stand half-way between the university and industry and possess elements of both, combining them in a network of relationships different from either the former or the latter.

The disjunctions between applied and pure science and research and development had to be transcended and replaced with a synergistic relationship. Inherent in such a conception was the

understanding that technology did not automatically flow from science. What had to be created was a set of structures that facilitated this translation. Instead of science and technology being polar worlds, one confined to the university and the other to the factory, there was the need for a proper passage between them. The industrial research laboratory was a set of structures that would increase the probability of a scientific idea being converted into a technological product. Kitchlu saw the most likely of these structures in the newly developing materials-science laboratories abroad. The new departments of materials-science redrew the boundaries between a scientific and a technological community, which provided a better background for the practical exploitation of research. Kitchlu articulated what Rustom Roy, Sietz, Harvey Brooks and von Hipel had already recognized—the necessity of creating a symbiosis between science and engineering, and of increasing the probability of interaction between these still distinct worlds. Such a conception is present in von Hipel's description of his molecular engineering laboratory at M.I.T. The passage from science to technology was visualized as a movement over thresholds. As Hipel remarked:

What we tried to create in this situation are truly interdepartmental laboratories. The strong foundation is fundamental research leading into the unknown for the sake of knowledge only. After new knowledge has been acquired, questions can be legitimately asked about practical applications. Thus from the first floor of the house, mainly populated by scientists, we reached the second where one dreams of long range applications. Finally the development stage has been reached, the problem passes to the top floor for the development of prototypes.

Such a laboratory structure challenges any kind of talent found in the schools of science and engineering, from the mathematical and theoretical physicist to the wizard of devices. Here the physicist cannot explain away difficulties with impunity, the engineer's prototype does not work and the real answer is required. Here the ceramist cannot persist, in the old established method of handling materials. The scientist inquiring into the phenomena of a new order of complexity, sees what a single crystal can accomplish and asks why ceramics cannot compete. Here is a feedback between all activities, stimulating thinking and critical appraisal. The modern research teams of science and engineering when combined in one laboratory allow a more searching approach from many angles, and specialists able to handle them work as allies. There is no excuse for doctoral students to remain narrow-minded, their research problem fits

into a broader context and may be pursued with any promising tool of any discipline under expert guidance. (von Hipel, 1956, p. 317.)

Von Hipel's laboratory was visualized as a grand alliance of physicists, chemists, electrical and chemical engineers, ceramists, mechanical engineers and metallurgists. The alliance was a historically appropriate one, responsive to the inter-disciplinary tradition of the new scienticized technologies which applied a fundamental understanding to the manufacturing of engineering devices.

In the discussion so far, we have dealt with the relation of the parts—pure science to applied science, of science to engineering. It is now appropriate to approach the whole, to say something about the nature of the industrial research laboratory. Let us avoid euphemisms, for they disguise a reality we must confront. The industrial research laboratory is a factory, it is a new kind of factory which involves the application of the scientific method to the manufacture of technology. Technology, which was once mainly empirical, now originates from theoretical principles. But the impact was not merely one way, science to technology, university to industry. Once the economic value of science to the innovation process was realized, science itself was transformed. It had to submit to the industrial order, and its discipline. The scienticization of technology was coupled with the industrialization of science and the interaction of these two cultures produced a new organizational mix—the industrial research laboratory.

Unlike the conventional factory, which has its Engels and its Taylor, the new knowledge factory has not received the attention it deserves from the sociologists. Few attempts have been made to unravel its contradictions, to visualize it as a new entity, a new institution with a personality of its own, placing demands on the individuals who enter it. The industrial research laboratory is as much a factory system as the Ford production line and as fascinating an organizational innovation—the institutional basis of the scientific industry. It has its genesis in the laboratories of Liebig at Gessen where, as Jorge Sabato, points out, 'Science—not only its findings but what is more important its method—began to be applied intentionally to the production of technology which resulted in such successes as the synthesis of aspirin by Bayer in 1899.' (Sabato, 1975, p. 38.) Sabato remarks that 'this was put on a more professional footing by Edison who was the first manufac-

turer of technology in the modern sense of the term. His laboratory at Menlo Park was organized thoroughly on a workshop basis. Hundreds of inventions were made there (the voltage regulator, several types of dynamo, the electric filament lamps, fuse insulating materials.' (Sabato, 1975, p. 38.) The necessity of confronting the reality of the laboratory as a factory has been emphasized by Harvey Brooks. His general comments are specifically applicable to the NPL:

a paradox often met with in government laboratories is a contrast between the high standard of scientific performance of the research workers and the poor results achieved by the institutions as a whole. What usually happens is that these government laboratories (with such titles as 'National Industrial Research Institute', etc.) are set up to fulfil the objectives of a factory of technology, but then organized along the lines of university laboratories. Consequently, these scientists think that they are working for a research laboratory as a rule, that is what these institutions are called . . . and so take it that it is their duty to produce good science, which is what they do. On the other hand, they do not manufacture technology, which is why the institutions were set up, and it is not therefore surprising that such a body should fail in its essential purpose. (Brooks, 1967, p. 46.)

The elucidation of this new knowledge factory constitutes a key task for future research.

The recognition of the laboratory as a factory for the scienticized production of technology leads us to another aspect of our argument. The scientists, in attempting to unravel the phenomena of industrial research, concentrated on the scienticization of industry, but were caught unawares by the industrialisation of science. The industrialization of science is evident in the presence of the pilot plant in the laboratory, in the recruitment of the daily worker and in the rise of unionism. The bulletin of the Association of Scientific Workers of India (ASWI) reveals that unionism is a fast-growing phenomenon in National Laboratories, forcing a recognition that the scientist is merely another kind of technical worker in industry. The phenomenon of unionism in the laboratory also raises certain specific issues within the politics of scarcity in India. This argument was made by a former president of ASWI, K. R. Bhattacharya. Commenting on a memorandum to the Ray Commission which dealt with the relative claims of the scientist and the administrator, Bhattacharya remarked:

It is contended that scientists contribute more to the country's development and hence their pay should be more; that I.A.S. men have a monopoly over superior posts and come between scientists and ministers; that there exists the supremacy of administrators, and scientists have been given second place; that the relative importance of professional groups should be reflected in pay scales; and that pay-scales are more favourable for administrators than scientists. I am afraid I violently disagree with this approach. Please do not misunderstand me, but it is a question of basic understanding and basic philosophy . . . do you mean to say that if scientists are given responsibilities they will just bring in heaven? In my opinion they will be as useless and worthless as under the prevailing conditions. Let us be very clear that the absence of development is not because of more importance to administrators and less to scientists, but due to much deeper social, economic and political factors . . . I am sorry if I have spoken strongly on this, but I believe strongly in it. It is time that we scientists consciously analyse our social role and critically judge how far our demands are for our own self-interest and how far for the sake of the country. If it is for the sake of the country, we have no option but to condemn the policy that the relative importance of different professional groups should be reflected in their pay scales. This way may be good for self-benefit, but then let us not talk of the country's development. (K. R. Bhattacharya, 1971, p. 10.)

We identified the industrial research laboratory as a special kind of factory but we still have to locate it in terms of the conventional factory of industry. We pointed out that this required a comprehensive understanding of the innovation chain, a recognition of the distinction between invention and innovation.

Invention refers to a new idea or technique. Innovation refers to the application of this idea or technique to the actual processes of production. Between invention and innovation lies a pre-testing stage, which demands pilot-plant activity. A pilot plant is a miniature factory, an attempt to stretch science on to the production line. In this context we pointed out the importance of conceptualizing the different kinds of exchange relationships between laboratory and industry. A distinction was formulated between the transfer of product technology, which involves contract, and the transfer of process technology which involves exchange, demanding a relationship of continuity and reciprocity. In addition, it was recognized that the role of the pilot plant in industrial research was misunderstood. The scientists failed to realize that research cannot be enacted purely on the laboratory

bench. They did not realize that one prototype solves problems only partially, and felt that the problem of ensuring repeatability on a mass scale was not the task of the laboratory. This confusion was also felt by the entrepreneur who failed to realize that the pilot plant was a half-way house between theoretical possibility and commercial feasibility. For example, the BEL management seemed to over-emphasize the pilot plant's potentialities as a factory. This opinion was in stark contrast to the scientists' who felt that mundane production problems were not their responsibility.

The Kane Commission, instituted by the CSIR to go into the problems of pilot plants, merely clouds the issue further. With the mentality of a cost-benefit ledger, the Commission suggested that it would be more reasonable in terms of efficiency and foreign exchange to buy technology, rather than duplicate it. The Commission stated that the 'tendency to set up experimental production units at the cost of the government to convince entrepreneurs, should be given up in view of the experience that such expenditure usually proves infructuous' (Kane report, 1971, p.n.a). The scientist's response to the Commission's report is revealing.

Laboratory-scale experimentation does not lead to consistent results or provide for the variations in raw materials. To indigenize a process and adapt it to Indian conditions requires the operation of an experimental pilot plant. When the laboratory passes on the process for commercial exploitation it should be able to help the entrepreneur with his teething troubles of scaling up production. This experience can only be gained by undertaking pilot-plant production in a limited scale in the laboratory. The Kane Commission took a facile attitude to the problems of technology absorption and failed to visualize the innovation chain as one long learning process which one has to traverse before obtaining a turnkey technology. The adaptation of foreign technology and its further development requires a prior replication at the pilot-plant stage. (Ramamurthy, 1971, p. 8.)

However, the Kane Commission in its recommendations proscribed the use of pilot plants for this very purpose.

The confusion in India about pilot plants in industrial research brings us to the wider conception of the innovation chain itself. The concept of the innovation chain visualizes the whole gamut of

activities from a scientific idea to actual commercialization as one fluid rationalized set of activities. But conceptualization alone is not enough, for a basic problem is to translate it into a series of institutional structures incorporating the vision of innovation as an integrated whole. For example, there is the necessity of visualizing a continuous flow of information between laboratory and production unit. The National Research and Development Corporation, which mediates between the laboratory and the entrepreneur, hardly bothers to insist on an information flow beyond the first contract and the handling of the later problem of developing technology depends entirely on the probable relations between laboratory scientists and production men.

It was this need for continuity between the various aspects of the innovation chain that Blackett emphasized, in his Nehru Memorial Lecture, when he observed that

the problem of transfer along the chain from research to production is often difficult, even within a single firm. It is still more difficult for a research laboratory or a government station to get its research taken up by firms. In India little research is done by firms whether private or state, and nearly all in government research establishments. This being so it is quite vital that some means should be found to take care of the later stages of the innovation chain. In any case, whenever a major project of research, development or design is embarked on in a government establishment, the latter stages of production, sales and marketing should be planned at the same time. It is not sufficient to embark on an R & D project and then hawk it to an unsympathetic industry which has never been properly consulted about the project. (Blackett, 1973, p. 13.)

In our case study of the transfer of technology, it was this risk of discontinuity that forced the NPL to become its own entrepreneur in order to ensure a genuine relationship of exchange between laboratory and production unit.

The theme of this chapter is the basic disjunction between science and technology. It emphasizes that the industrial research laboratory as an organization must create the most likely world for the translation of science into technology. This involves entrepreneurship, which is primarily an attempt to bridge the discontinuities between the two. T. V. Ramamurthy attempted this, but while effort was commendable, it had one fatal flaw. He bridged the disjunctions by operating a highly active personal network.

Ramamurthy was a student of telecommunications engineering at the Indian Institute of Science, Bangalore. Present simultaneously at the Institute were Bhabha, Sarabhai, Baliga and a host of other scientists who were to occupy leading positions in the fields of science and technology in independent India. Through his contacts, which he used with great resource and skill, he managed to create an *ad hoc* network which enabled him to traverse the innovation chain. But when Baliga retired and Bhabha and Sarabhai died, his network folded up. As he himself admitted, his basic failure was not scientific but organizational. He failed to create a series of impersonal institutional structures which would assure a smooth continuity between science and technology.

In locating the industrial research laboratory within the wider processes of development and underdevelopment, we emphasized that the structure of industrial research outside India was an institutional system of obsolescence, imposing a literal death on a whole series of primary-product societies. It became clear that the threat to lac, jute, mica, silk and cotton convinced scientists in India of the need to establish industrial research laboratories to counteract the trend. But buildings alone were not enough. The laboratories were structures without the appropriate consciousness to focus on the problem of primary products. The scientific community in India still had its centre in the Western metropolis where the invisible college was located. Science in these countries was integrated with the requirements and demands of its technology, demonstrated by the development of materials science. This new sub-culture of scienticized technology was created in order to cope with the problems of technology in defence, electronics, space and transportation and was helped on its way by the defence and industrial establishment and the university community. No similar attempt has been made in India to create a structure combining excellence and relevance, maintaining accountability and yet allowing to science the autonomy its creativity demands. Ben David's argument is worth quoting here. 'Scientists have found it more congenial to be guided by the logically inherent problems and methodologically determined potentialities of a paradigm common to a group of scientists, than by considerations of practical use. They become stale and sterile when subjected in their work to extraneous considerations over a long period of time.' (Ben David, 1968, p. 58.) He adds:

The practical uses of science should be conceived as the result of chance interactions between fundamental discoveries on the one hand and practical interests on the other, which can occur in an infinite variety of ways. The purpose of policy should, therefore, be to influence the likelihood of these chance occurrences by increasing the density of both kinds of activities and the velocity of the circulation of ideas and problems from both areas of activity in spaces which ensure interaction. Increasing the density is a matter of investment, velocity is the result of entrepreneurship, and creating properly enclosed spaces is the task for organization. (Ben David, 1968, p. 61.)

This, in short, is the problem of industrial research—to create the most probable world for the fruitful interaction of science and technology.

The controversies in India surrounding the reorganization of the CSIR reveal the need for the sociological approach to science. The debate demonstrated that little attempt had been made by policy-makers to understand industrial research within the wider structures of the innovation chain. The disillusionment with industrial research is an inversion of the euphoria of the early Nehru era. But it also reflects the deeper dissatisfactions with current paradigms of science and technology in India, and shows the import-substitution model to be at the end of its tether. The cracks of doubt may one day inaugurate a regime of new possibilities. There is a need for analysis and herein lies the role of sociology.

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